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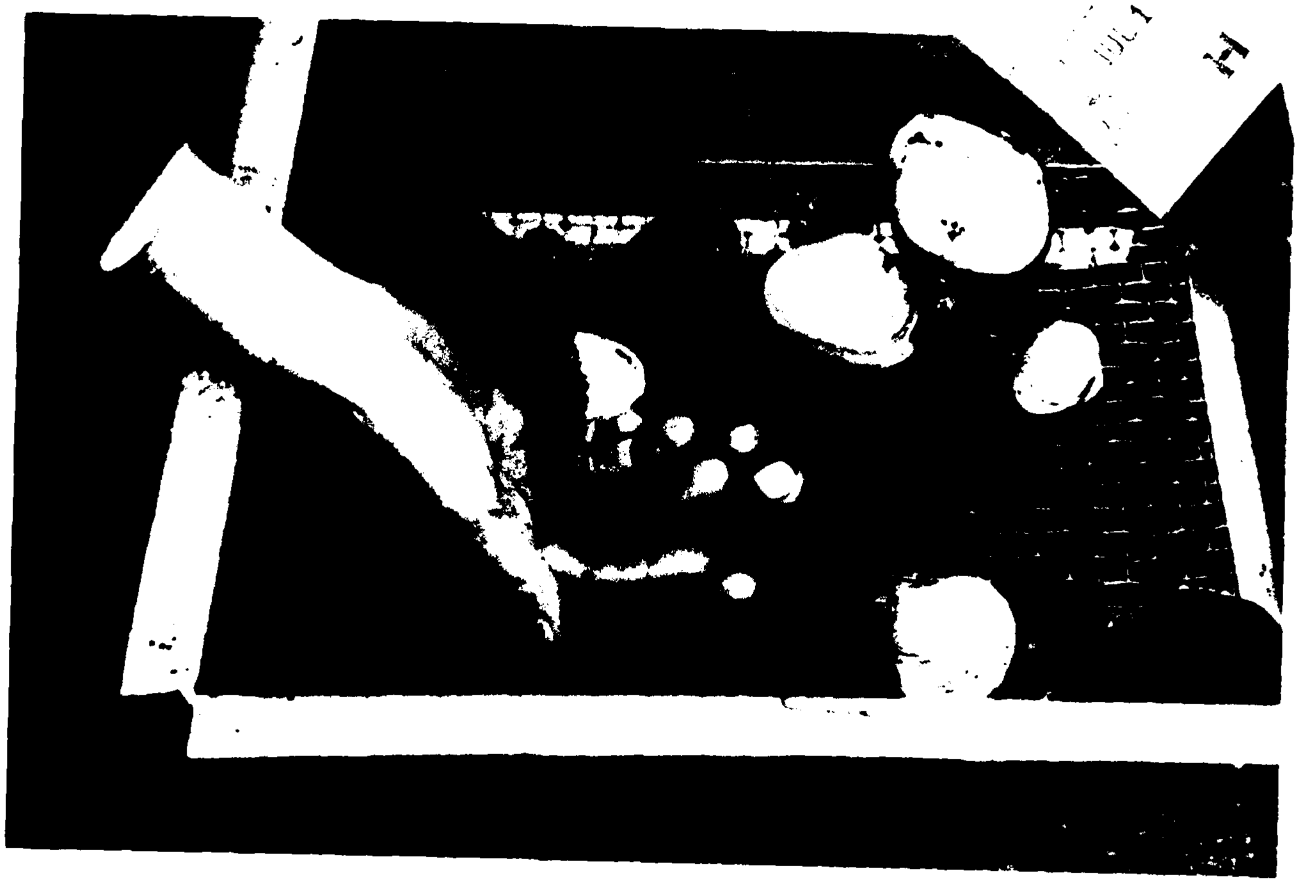
GRAYS HARBOR AND CHEHALIS RIVER
IMPROVEMENTS TO NAVIGATION
ENVIRONMENTAL STUDIES

BENTHIC INVERTEBRATE STUDIES IN GRAYS HARBOR, WASHINGTON



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Benthic invertebrate assemblages at five intertidal and seven subtidal sites in Grays Harbor, Washington, were assayed with special emphasis on benthic macroinfauna. Quantitative samples were taken seasonally at all sites, and often at several elevations within site. Invertebrate assemblages were recorded for each season, and Shannon-Wiener diversity values were calculated. Intertidal diversity values generally increased with decreasing elevation. No clear seasonal patterns of change in diversity at each elevation were evident.

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However, lowest diversity values occurred at Cosmopolis (the least saline site) while the most oceanward intertidal site (Moon Island) had generally high diversity values. Subtidal diversity values generally increased from the inner harbor to the outer harbor.

Organisms characteristic of the inner harbor included *Manayunkia aestuarina*, *Corophium spinicorne*, *C. salmonis*, *C. brevis*, *Gnorimosphaeroma luteum*, *Streblospio benedicti*, *Macoma balthica* and Oligochaetes. Species characteristic of outer harbor stations were *Paraphoxus milleri*, *Magelona sacculata*, *Armandia brevis*, *Archaeomysis grebnitzkii*, *Ophelia limacina*, *Scoloplos armiger* and *Tellina nuculoides*.

Cow Point had the highest observed total biomass of any intertidal site. Total biomass of infauna at subtidal sites showed no clear trend with respect to position in the estuary.

Multivariate analysis of the data were used to produce dendrograms of seasonal changes in invertebrate diversities on intertidal and subtidal sites. Salinity, elevation and sediment type are all important in determining community structures of invertebrates on intertidal sites. Subtidal stations generally had greater variation in assemblages than intertidal stations at the same site. Subtidal stations possessed more unique benthic communities than intertidal stations.

Probable impacts on benthos from widening and deepening are presented. We do not expect fauna in the channel to be totally eliminated by dredging. After dredging, we expect recolonization to occur. One and six-tenths hectares of intertidal habitat will be converted to subtidal habitat by dredging. Unquantified loss of shallow subtidal habitat is more significant. Mitigation of impacts to the benthos may be achieved by dredging in late winter or early spring; February through April. This is based on the conclusion that large numbers of juveniles entering the system in spring would quickly colonize exposed sediments.

COVER PHOTOGRAPH: Example of benthic organisms from core samples.

DISCLAIMER

Data, interpretations, and conclusions in this report are those of the authors.

WASHINGTON STATE

DEPARTMENT OF GAME

ABERDEEN, WA

98520

BENTHIC INVERTEBRATE STUDIES

IN

GRAYS HARBOR, WASHINGTON

By

Richard Albright

Patricia K. Bouthillette

Work performed for the Seattle District U.S. Army Corps of Engineers under Contract Number DACW67-80-C-0091.

EXECUTIVE SUMMARY

Objectives of the study:

1. determine temporal aspects of species composition, abundance and biomass of macroinfaunal and macroepifaunal assemblages located in areas where impact on these groups of organisms by proposed dredging activity in Grays Harbor may occur;

2. evaluate similarities and differences in assemblages of sites within the estuary; and

3. suggest possible means to mitigate adverse effects of the proposed dredging on benthic invertebrate assemblages.

Intertidal:

1. In general, species diversity increased with decreasing elevation, and from the inner to the outer harbor. Abundance of invertebrates was highest at the Marsh Establishment site during spring and highest at the Cow Point site during other seasons. General abundance of invertebrates was highest in summer and lowest in spring. Biomass, including infaunal and epifaunal invertebrates, was highest at the Cow Point site, and lowest at the Cosmopolis site during all seasons. When epifauna are excluded, invertebrate biomass was highest in spring and lowest in summer. Annelid worms were the most important faunal group, by number, at every site.

2. Three species (<u>Manayunkia aestuarina</u>, <u>Corophium spinicorne</u>, and <u>C. salmonis</u>) dominated invertebrate assemblages. Salinity, elevation, and sediment type were all important in determining dissimilarity between stations and sites. The affect of these three physical parameters on these three species accounted for most of the dissimilarity observed between sites and stations.

Subtidal:

1. Diversity values increased from East to West in the estuary. Diversities on the channel bottom and channel side varied with season and showed no consistent pattern. Overall diversity values were lowest in spring and highest in autumn. Cosmopolis site had the highest abundance of invertebrates during all seasons. Deepwater Disposal site and channel bottom at the Moon Island site had consistently low abundances of invertebrates. Total biomass of invertebrates, including epifauna was highest at the South Jetty site and Cosmopolis Channel site side station. If epifauna are excluded, no clear special trends in biomass are evident. Total biomass was highest in winter and lowest in summer.

2. There were two major site groupings, inner harbor sites and outer harbor sites. Greater variation occurred in subtidal sites than intertidal sites. The Top of the Crossover Channel site was on the boundary between these groupings. Stations from this site were found in both groups. Variance in assemblages among the sited increased during summer and decreased during winter.

Changes associated with increased freshwater flow from the Chehalis River may account for this.

3. Several "opportunistic" invertebrate species inhabit Grays Harbor. These species may quickly colonize a disturbed area if dredging takes place during late winter and early spring, before the onset of increased breeding activity.

ABSTRACT

Benthic invertebrate assemblages at five intertidal and seven subtidal sites in Grays Harbor, Washington, were assayed with special emphasis on benthic macroinfauna. Quantitative samples were taken seasonally at all sites, and often at several elevations within sites. Invertebrate assemblages were recorded for each season, and Shannon-Wiener diversity values were calculated. Intertidal diversity values generally increased with decreasing elevation. No clear seasonal patterns of change in diversity at each elevation were evident. However. lowest diversity values occurred at Cosmopolis (the least saline site) while the most oceanward intertidal site (Moon Island) had generally high diversity values. Subtidal diversity values generally increased from the inner harbor to the outer harbor.

Organisms characteristic of the inner harbor included *Manayunkia aestuarina*, *Corophium spinicorne*, *C. salmonis*, *C. brevis*, *Gnorimosphaeroma luteum*, *Streblospio benedicti*, *Macoma balthica* and *Oligochaetes*. Species characteristic of outer harbor stations were *Paraphoxus milleri*, *Magelona sacculata*, *Armandia brevis*, *Archaeomysis grebnitzkii*, *Ophelia limacina*, *Scoloplos armiger* and *Tellina nuculoides*.

Cow Point and the highest observed total biomass of any intertidal site. Total biomass of infauna at subtidal sites showed no clear trend with respect to position in the estuary.

Multivariate analysis of the data was used to produce dendrograms of seasonal changes in invertebrate diversities on intertidal and subtidal sites. Salinity, elevation and sediment type are all important in determining community structures of invertebrates on intertidal sites. Subtidal stations generally had greater variation in assemblages than intertidal stations at the same site. Subtidal stations possessed more unique benthic communities than intertidal stations.

Probable impacts on benthos from widening and deepening are presented. We do not expect fauna in the channel to be totally eliminated by dredging. After dredging, we expect recolonization to occur. One and six-tenths hectares of intertidal habitat will be converted to subtidal habitat by dredging. Unquantified loss of shallow subtidal habitat is more significant. Mitigation of impacts to the benthos may be achieved by dredging in late winter or early spring: February thru April. This is based on the conclusion that large numbers of juveniles entering the system in spring would quickly colonize exposed sediments.

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PROJECT PERSONNEL

Jack Howerton was principal investigator. He initiated the study and provided administrative and technical support throughout its duration.

Stephan A. Kalinowski was project leader. He directed research, and supervised project biologists and assistants.

Rick Albright and Patricia Bouthillette were the biologists responsible for collection, analysis, and writing of this report. Results of their efforts, in edited form, are presented in this paper.

Gene McKeen assisted project biologist with collection and preparation of specimens.

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INTRODUCTION

Grays Harbor is the third largest estuary in the Pacific Northwest (Proctor et al. 1980). The estuary is approximately 29 km long and 21 km wide at its widest point and is located 145 km southwest of Seattle (Gatto 1978). Sixteen percent (15.33 km^2) of the area between mean lower low water (MLLW) and extreme high water (EHW) is undiked salt marsh. At MLLW, 58% of the estuary is mud flat (Loehr and Collias 1981).

In April of 1980, Seattle District, U.S. Army Corps of Engineers contracted with Washington Department of Game, for the study of benthic invertebrate assemblages and growth and reproductive rate of the crustacean Corophium. This was one of many environmental studies designed to address impacts of widening and deepening the navigation channel in Grays Harbor. The proposed navigation project would require initial dredging of an estimated 17.6 million cubic meters (c.m.) of material and annual maintenance dredging of approximately 2.5 million c.m. of material to maintain proposed channel depths. Intertidal and subtidal benthic invertebrates in and adjacent to the existing navigation channel will be removed by this channel improvement project. A portion of the habitat suitable for the re-establishment of these invertebrate assemblages may be adversely affected by dredging. To identify and quantify the organisms that will be affected, and to determine the relative importance of the benthic communities in these areas to fish and waterfowl, benthi invertebrates were quantitatively sampled periodically in several locations in Grays Harbor.

Objectives of this study were:

1. Determine species composition, abundance, and biomass of macroinfaunal and macroepifaunal assemblages located in areas where impact on these groups of organisms by proposed dredging activity in Grays Harbor may occur;

2. Evaluate similarities and differences in assemblages of sites within the estuary.

3. Suggest possible means to mitigate adverse effects on benthic invertebrate assemblages of the proposed dredging.

LITERATURE REVIEW

Albright and Rammer (1976) have succintly summarized available literature pertinent to this type of study.

Estuaries with extensive areas of mudflats are subject to continuous disturbance by biological and physical activity. Such disturbance leads to resuspension of sediments in the water column (Peterson and Peterson 1979). This situation maintains an environment in which species (eg. Spionidae, Capitellidae, and Nereidae) adapted to recolonization of disturbed areas thrive (Peterson and Peterson 1979, Nichols 1979). Physical changes in estuaries which increase or decrease the freshwater component also cause associated changes in the biota (Nichols 1979). An increase in salinity and generally leads to increased diversity within the system (Remaine and Schlieper 1971).

Physical disturbance or destruction causes drastic decreases in numbers of benthic and epibenthic invertebrates (McCauley, Hancock, and Parr 1979; McCauley, Parr, and Hancock 1976; McCall 1977). Recovery apparently occurs within 6 or 7 weeks even in estuaries with regular maintenance dredging activity or ship traffic (McCauley, Parr, and Hancock 1977). If dredging activity ceases, recovery of benthic communities to predredging levels is expected to occur within 12-18 months (Swartz et al. 1980).

Because of the difficulty in determining relationships and importance of all the changes that occur in estuaries due to natural causes or man-made activities, a unifying approach using rate-of-sediment-turnover (RST) and organic-content-of-the-sediment (OCS) has received recent exposure in the literature (Bella and Williamson 1980, and Bella et al. 1977). Basically, this approach uses these factors (RST and OCS) as common denominators for comparisons of benthos before, during and after dredging operations. This technique has been applied in part in this report.

STUDY AREA

Seven subtidal and 5 intertidal study sites were located in the lower Chehalis River and Grays Harbor (Fig. 1). Site descriptions are arranged East to West, starting with Cosmopolis and ending with South Jetty.

Cosmopolis (Site C): was furthest east; therefore, salinity was lowest at this site. Salinities here vary from zero to 14 parts per thousand (ppt) and temperatures range from 2 degrees to 19 degrees Celsius (Loehr and Collias, 1981). This sampling site was located on the outside (west side of river) of a large bend in Chehalis River. Thus, sampling stations of the site were exposed to severe currents during high river flows.

Two major industrial facilities are located nearby. The first, a Weyerhaeuser Company pulp mill is approximately .5 km upstream. There was no processing waste outfall from this mill. There was, however, a wash-water outfall. Average flow from this outfall is 3.02×10^{6} liters per day (ld). The second facility, Cosmopolis sewer plant, had an outfall located 30 meters downstream from the site. Average flow from this outfall was 1.51×10^{6} ld. A public boat launch ramp is situated nine meters upriver from the site.

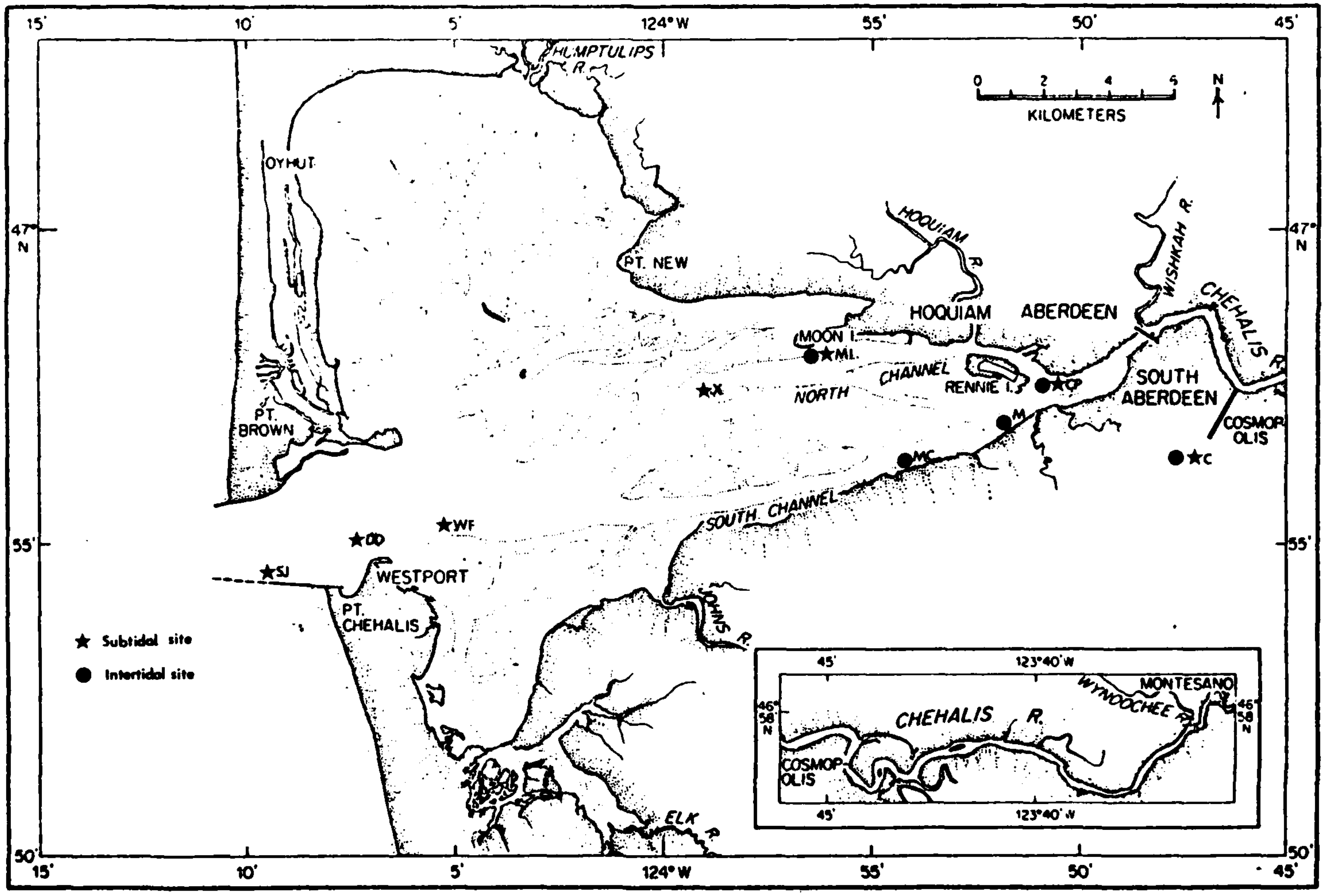

Figure 1. Benthic invertebrate sampling site locations in Grays Harbor, Washington.

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The intertidal area at Cosmopolis consisted of a narrow, terraced beach between ordinary high water (OHW) and MLLW. The 1.22m (+4') station was located at the base of the terrace, and the 2.14 (+7') station was near the upper margin of the terrace. The terrace was reinforced with old lumber. One-third of the intertidal area (which was on top of a terrace) was a sedge (Carex lyngbyei) marsh. At its lower margin, there was a one meter drop-off to a cobble and gravel beach with old pilings, logs and metal debris. In winter, erosion along the edge of the terrace was evident. A thin layer of silt was evident on the lower cobble beach. The drop-off was less abrupt in winter than at other times of the year.

The 2.14 meter station was in the sedge marsh. The dense root system extended beyond a depth of 8 cm. The substrate was composed of silt (65%), clay (17%), and fine sand (18%). The average percent total volatile solids was 8.20%.

The 1.22 meter station had a predominantly gravel substrate (70%), with some sand and silt present. A layer of silt covered this staion during winter. Pieces of an old wooden bulkhead were present, especially on the eastern (upstream) half of this station. The presence of wood fragments was probably the reason this station had the highest percentage of total volatile solids (12.42% in summer) of all intertidal stations (Appendix B, Tables 1 and 2).

The MLLW station also had a predominantly gravel (63%) and coarse seand (21%) substrate. In summer, the average percent

Cow Point (Site CP): was located on the north side of the navigation channel.(Fig.1) This site was characterized by low salinity values and close proximity to sources of industrial pollution. The site was adjacent to a Port of Grays Harbor log storage yard and 50 meters west of Terminal No. 4. Pollution sources of present in the vicinity of the Cow Point site included the City of Aberdeen sewage plant outfall, located approximately one km upstream. Adjacent to the site and on both sides were outfalls from loq storage yards and an outfall from ITT Rayonier pulpmill. "The Cow Point area is located one km east of the mill outfall and receives mill effluent in a direct line from the outfall on the incoming tide" (Hoffman et al., 1981). In 1980, the ITT pulp mill had an average daily discharge of 9.8×10^7 ld. In 1981, during times of benthic sampling, the average outfall volume was 3.7×10^7 ld. (Schaaf, personal communication, 1981)[1]. Loehr and Collias (1981) stated that Cow Point is an area with depressed levels of dissolved oxygen (DO). However, this situation has improved in recent years. Hydrogen sulfide was evident when on this site.

Like Cosmopolis, strong currents occur at Cow Point, preventing silts and sands from settling over the rocks and cobble above MLLW. Salinity at Cow Point range during the year from 2 to 23 ppt, while temperatures range from 2 to 18°C. (Loehr and Collias 1981.)

[1] Jerry Schaaf, ITT Rayonier, Hoquiam, Washington.

An average salinity of 17 ppt during summer and 9 ppt during winter were reported by Herrmann et al. (unpublished data, 1982).[2]

The intertidal site consisted of a narrow beach approximately 15 meters wide, between MLLW and OHW, with a fairly steep but even slope. The beach was bounded at its upper edge by riprap.

At 2.14 meters the beach was comprised mostly of riprap with gravel and sand present between these larger rocks. In summer, grain size was 87% gravel. This value was biased because large cobble and boulders could not be included in the grain size analysis. However, since sampling was done in the gravel and sand between or under rocks and cobble, the grain size analysis represents the actual habitat sampled. This station had the highest total volatile solids (27.05%) of any station sampled during 1980-81.

Although cobble and gravel were prevalent on the sediment surface at 1.22 meters, fine sand and silt were present on the surface between rocks and comprised most of the underlying sediments. In summer, sediment size composition values were 32% fine sand and 39% silt. Again, the grain size analysis was biased by the absence of cobble in the sample. In summer, the total volatile solids value was 6.41%, considerably lower than the value obtained at 2.14 meters.

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2 Robert E. Herrmann, Weyerhaeuser Company, New Bern Forestry Research Station, New Bern, North Carolina 28560.

The substrate at the MLLW station changed sharply; cobble and gravel were replaced with fine sand and silt. The boundary between substrates lay such that half of the MLLW station was in the exposed sandy silt area, and the other half was in the cobble/gravel/sand/silt substrate. In summer the substrate was composed of 61% fine sand and 25% silt because the randomly placed grain size analysis sampling point was located in the finer sediments. In summer the average total volatile solids value was 6.19%.

The channel side was sampled at approximately 5.8 meters below MLLW. Sediment composition varied with season. In spring, sediment grain sizes were predominantly silt (43%) and gravel (24%). Total volatile solids was 8.84%. In summer, predominant grain sizes were silt (62%) and clay (21%). Total volatile solids value of 8.82%, was nearly identical to spring values, 8.84%. In both autumn and winter, the substrate consisted entirely of soft mud (silt and clay).

The channel bottom was sampled at an average elevation of -12.2 meters. As at the channel side station, sediment composition varied with season. In spring, predominant grain sizes were silt (55%) and fine sand (30%). The percent total volatile solids was 5.53%. In summer gravel comprised 99% of the substrate. The percent total volatile solids in summer was 1.29%. The substrate at this station had the highest percent gravel and lowest percent of volatile solids of any inner harbor subtidal or intertidal sites. In autumn, the substrate was mud overlaying a hard, clay sediment, and in winter, the substrate was a mud slurry.

Marsh Establishment (Site M) (Fig.1): The intertidal region at the Marsh Establishment Site consisted of a broad mudflat approximately 230 meters wide between MLLW and OHW. Near MLLW, a few old pilings and various pieces of wood, metal and cement debris were left over from days when this area was used for log storage. Water-logged trees and stumps were scattered throughout the mudflat. The beach was bounded at its upper margin by riprap and patches of salt marsh. Salinity average 19 ppt in summer and 11 ppt in winter (Herrman et al., unpublished data, 1981).

The upper beach, between approximately +1.2 meters and +2.2 meters, was vegetated with eelgrass (*Zostera* spp.). During the summer and early autumn, benthic diatoms were also visible on the sediment surface. Below +1.2 meters little or no vegetation was visible. Brown alga *Fucus* grew on old pilings and waterlogged trees throughout this intertidal area. Situated one km to the east was the Weyerhaeuser pulp mill outfall with an average flow of 8.0×10^7 ld.

This 2.14 meter station was located partially in a sedge (*Carex lyngbyei*) marsh that started slightly below 2.14 meters and continued to the base of the riprap, approximately 2.5 meters elevation. The substrate was predominantly silt (79%-91%). Total volatile solid values were 8.39% in spring and 10.01% in summer. The substrate at 1.22 meters was predominantly silt (57%-66%) with fine sand (22%-29%). The average total volatile solids were 6.06% in spring, and 6.54% in summer.

Two types of substrate were present at the MLLW station: a finer substrate (fine sand, silt and clay) and a more coarse material (gravel and coarse sand)(Appendix B, Table 1). Substrate at the MLLW station was the coarsest substrate at site M. Areas of gravel, rocks, and debris were nearby. A few tidepools were present. Average percent total volatile solids were lowest here for any station at site M. In spring, the average percentage was 5.74 and in summer 5.68%.

Marsh Control (Site MC) (Fig.1): was a broad, gently sloping mudflat approximately 275 meters wide. Located 3 kilometers west of the Marsh Establishment site along the South Channel, the mudflat was bounded on its upper edge by a strip of salt marsh vegetation 15 meters wide. At approximately one meter in elevation the mudflat began to drop off sharply into the South Channel. Thus the MLLW station was on a moderately steep slope ($\pm 10^{\circ}$). The area above 1.5 meters was covered by a moderately dense eelgrass bed (Zostera spp.). During summer and early autumn, growths of benthic algae and diatoms were visible on the sediment surface. Associated with this were the appearance of hummocks of bottom materials 2 to 5 cm high, scattered throughout the upper intertidal region. Salinity averaged 22 ppt in summer and 12 ppt in winter (Herrmann et al., unpublished data, 1981).

The substrate at the 2.14 meter station was predominately silt (81%-84%) with clay comprising most of the remaining sediment. In spring and summer. average percent total volatile solids were 9.41 and 9.15 respectively.

At the 1.22 m station silt comprised 70% to 80% of the sediment with clay comprising most of the remaining substrate. Average percent total volatile solids were 8.32 and 6.23 in spring and summer respectively.

The substrate at the MLLW station was composed primarily of silt, 80-84%. The remaining fractions of the sediment consisted primarily of clay. The substrate here was extremely soft and unconsolidated. During spring and summer, average percent total volatile solids were 7.70 and 6.60, respectively.

Moon Island (Site MI)(Figure 1): Intertidal stations were situated 3.2 km west of the mouth of Hoquiam River, along the north side of the main navigation channel. The beach consisted of a broad tideflat approximately 115 meters wide. At .6 meters above MLLW, the beach began to slope steeply, dropping into the navigation channel. The upper end of the beach was bordered by riprap which provided support for an adjacent paved road. City of Hoquiam sewage treatment pond is located across the road. An outfall (average flow of 15 ld), from this sewage pond was located 100 meters west of the site (Gregory personal communication, 1981).[3] The

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[3] Allan Gregory, Hoquiam Sewer Plant, Hoquiam, Washington

substrate was firm sand, hard-packed silt and clay. Salinity was higher at this site than at any other intertidal site. Dredging of the intertidal area one-half km east of the sampling site began in September 1980, in association with construction of a new pier. This may have caused appearance of a layer of silt and clay on the tideflat during autumn.

The substrate at the 2.14 meter station was composed almost entirely of fine sand (84%). Total volatile solids value was 1.98%. A sparse cover of eelgrass (Zostera spp.) was present at this station.

The 1.22 meter station was in an area riddled with large, dead Mya arenaria shells. These shells were oriented vertically and sticking partially out of the substrate. In summer, the sediment was primarily compact silt (65%) and fine sand (26%). The average total volatile solids in summer was 4.39%.

In spring, substrate of Moon Island MLLW station consisted of a matrix of soft areas interspersed with hummocks of hard, compact sediments. In summer, the sediment was more uniformly firm than in Spring. Erosion and/or accretion of sediments formed a small dropoff (8 cm high) at the MLLW station marker during summer. In autumn and winter the substrate had a consistent slope and firmness. It appears sediments at this station are quite dynamic and are subject to movements and alteration by currents, wave action, and disturbance from passing ships. In summer, sediment composition was predominantly silt (61%) and fine sand (28%). The average percent total volatile solids was 5.58%.

Salinity at the Moon Island subtidal stations ranged from 7 to 26 ppt, and temperature from 4 to 18 degrees Celsius (Loehr and Collias, 1981). The average summer salinity value was 22 ppt, while that for winter was 12 ppt (Herrmann et al., unpublished data, 1981).

The side of the channel was sampled at a depth range of -4.3 to 5.5 meters. In spring, sediment was composed of 48% fine sand and 31% silt. The substrate was hard-packed clay. The percent total volatile solids value was 4.85%. In summer, 65% of the substrate was silt, 18% fine sand, and 17% clay. The percent total volatile solids value increased to 7.20%, probably because of the increase in silt. In autumn, the substrate consisted of loosely consolidated silt and clay over hard-packed silt and clay, coarse sand was also present. In winter, the substrate consisted of very soft silt (5 cm thick) overlaying coarse sand.

The bottom of the channel at Moon Island was ampled at a depth of approximately -10.7 meters. In spring, the sediment was composed of silt (49%) and fine sand (40%). The percent total volatile solids was 8.16. The substrate was extremely soft having the consistency of pea soup. In summer, sediment was predominantly fine sand (65%) and silt (28%).

Top of the Crossover Channel (Site X) (Figure 1): Salinity at the Top of the Crossover Channel averaged 22 ppt in summer and 12 ppt in winter (Herrmann et al., unpublished data, 1981). Stations at this site may have been affected by maintenance dredging which occurred just prior to spring and summer sampling periods.

The channel side at the Top of the Crossover Channel was sampled at depths between -5.2 to 5.5 meters. In spring, predominant grain sizes were fine sand (65%) and silt (24%). The percent total volatile solids was 3.52%. In summer, sediments were primarily composed of fine sand (97%). The percent total volatile solids value was 5.32. The substrate was a slurry, with sand and wood debris present. In summer, predominant grain sizes were fine sand (46%) and silt (21%). The percent total volatile solids was 2.14.

The channel bottom station was sampled between -11.0 to 11.6 meters. In spring, predominant grain sizes were fine sand (62%) and silt (16%). The percent total volatile solids decreased to 2.53. In autumn, substrate was significantly different, consisting of coarse sand with some shell fragments. In winter, substrate was fine sand, silt, and clay.

Whitcomb Flats (Site WF) (Figure 1): Along with the Deep Water Disposal and South Jetty sites, represent those sites at which ocean influenc dominates freshwater influence of the Chehalis River. Salinity at this site averaged 28 ppt in summer and 20 ppt in winter. Wave action here is noticeably greater than at inner harbor sites. Even during calm summer days oceanic swells reach this part of the harbor. As a result very little silt or clay was present in the substrate. Fine sand constituted more than 90% of sediment samples. Correspondingly, low percentages of total volatile solids occurred. Maintenance dredging occurred at this site during all seasons except winter.

The Whitcomb Flats channel side station was sampled at an average elevation of -5.5 meters. Sediments at this station were composed almost entirely of fine sand (97 to 99%). Percent total volatile solids was again low. Throughout this study percent of total volatile solids was inversely proportional to the percent of silt in the sediment. The percent total volatile solids was 1.21 in spring and summer.

The Whitcomb Flats channel bottom station was sampled at an elevation range of -11.0 to -11.6 meters. Fine sand dominated sediment composition during all seasons. Percent of total volatile solids were 1.12 and 1.22 in spring and summer, respectively.

Deepwater Disposal (Site DD) (Figure 1): was located approximately 500 meters southeast of buoy "13" near the mouth of Grays Harbor. This site has been used in recent years for disposal of dredged materials resulting from maintenance dredging of the navigation channel. Depth of the site varied between seasons (-15.3 to -19.8 meters). Sediment composition also varied between seasons. This may result from deposition and movement of dredged material at the site incombination with natural sediment movement caused by wave and current action. During spring, sediments were composed almost entirely of fine sand (99%). During summer, fine sand comprised 65% of the sediment. Remaining sediment was mainly coarse sand. The percentage of total volatile solids was low, with spring and summer values of 1.23 and 1.29, respectively. Salinity at the site ranges from am average of 28 ppt in summer to an average of 20 ppt in winter. Dredged material disposal occurred at this during all seasons.

South Jerry (Site SJ) (Figure 1): was the western-most site sampled. This site was located 75-100 meters north of the south jetty and southwest of buoy "11". While the site was somewhat protected from wave action by the jetty, ocean swells were a major environmental feature at the site. In addition, strong tidal currents sweep along the jetty. Salinity here was comparable to that of the Deepwater Disposal Site. Substrate consists of cobble, gravel, sand, and clam shells, with occassional patches of coarse sand. The amount of cobbles and gravel in the sediment seemed to decrease with distance from the South Jetty. Grain size analysis of a summer sediment sampled showed sediment to be composed mainly of gravel (88%). The percentage of total volatile solids was 1.72. The bottom was -12.2 to 15.3 meters deep.

METHODS AND MATERIALS

A total of 5 intertidal sites and 7 subtidal sites were sampled for benthic invertebrates (Figure 1, Table 1). Samples were collected in spring (May 1980), summer (August 1980), autumn (November 1980) and winter (February-March 1981).

Intertidal sampling was done using a core sampler (13.2 cm^2 x 8 cm deep) and box sampler (.0625 m^2 x .3 m deep). At each site, stations were placed at mean lower low water (MLLW), +1.22 m and +2.14 m relative to MLLW and marked with either metal or wood stakes. Elevations were determined using a Zeiss level at sites M and MI; and with a hand held Berger level at all other sites. An elevation marker set adjacent to each site by U.S. Army Corps of Engineers surveyors was used as the reference. Samples were obtained from randomly selected locations along a 6 meter transect placed parallel to the shoreline, with the station marker located at the center of the transect.

Core samples were screened using Ponar Littoral Wash Buckets with a .5 mm mesh screen before a preservative was added. Box samples, collected to sample larger organisms, primarily clams, were screened with a 2.0 mm mesh screen. All samples were preserved in a solution of 5% formalin buffered with (anhydrous granular) sodium carbonate.

TABLE 1. Sites and elevations (stations) at which core, box, or grab samples were collected for the study of invertebrate fauna in Grays Harbor, WA, 1980-81. (x = sampled; 0 = not sampled)

Site	Core sample	Box sample			vanVeen Grab sample	
	all elevations	MLLW	+1.22m	+2.14m	channel bottom	channel side
Marsh Establishment Site (M)	X	X	X	X	0	0
Marsh Control (MC)	X	X	X	X	0	0
1 Cosmopolis (C)	X	X	X	0	X	X
2 Cow Point (CP)	X	X	X	0	X	X
3 Moon Island (MI)	X	X	X	X	X	X
4 Top of the Crossover Channel (X)	0	0	0	0	X	X
5 Whitcomb Flats (WF)	0	0	0	0	X	X
6 Deepwater Disposal Area (DD)	0	0	0	0	X	0
7 South Jetty (SJ)	0	0	0	0	X	0

Rose bengal, a stain, was added to the samples with the formalin and left for at least 24 hours.

Core samples were sorted into 5 general categories: annelids, crustaceans, clams, barnacles and others. Box samples were sorted into 4 categories: clam, crab, fish and other. After organisms were sorted into categories, they were preserved in a solution of 70% ethyl alcohol and 5% glycerol.

Interstitial salinity measurements were taken at each station during most of the sampling trips. A sample was also collected at the water's edge at low tide (below MLLW).

In May 1980-81 and August 1980, core samples were collected at each station for analysis of grain size and total volatile solids. Cores for analysis of grain size were collected to a depth of 8 cm, while cores for analysis of volatile solids were collected to a depth of 3 cm. These samples were analyzed at Grays Harbor College. Results are presented in Appendix E.

Subtidal samples were collected using a 0.1 m^2 van Veen grab sampler. During each season, 2 grab samples were collected from the bottom and 2 from the midpoint on the side of the navigation channel at Sites 1-5. At Sites 6 and 7, 2 grab samples were collected from the bottom. Because there is no defined channel at these sites, no channel side samples were collected. Grab samples were screened live using Icnar Littoral Wash Buckets with a 0.5 mm mesh screen and processed in the same manner as core samples.

In May and August 1980, core samples were collected for analysis of grain size and total volatile solids through a trap door on top of the grab sampler. Data on grain size and total volatile solids are presented in Appendix B.

Organisms were identified to species when possible. Hydroids, Entoprocta and Ectoprocta were identified to class. Wet weights of each general category (eg. Crustacea, Annalida, Mollusca, and other) in each sample were determined using a Mettler H6 Analytical Balance. Large organisms (eg. clams, crabs, etc) were weighed separately.

The Shannon-Wiener function (Krebs 1972:506) and Evenness values (Krebs 1972:507) were used to calculate diversity of invertebrate communities at the sites. Both formulas were modified from those presented in Krebs by computing logs to base e rather than base 2.

The index developed by Shannon and Wiener to determine H* is:

$$H^1 = -\sum_{i=1}^{S} (p_i)(\log p_i)$$

S = number of species

p_i= proportion of total sample belonging to ith species.

Eveness (E) values were calculated as follows:

$$E = \frac{H^1}{H\ max}$$

$$H\ max = Log_e S$$

After square root transformations of the raw data, cluster analysis was done using the Bray-Curtis Dissimilarity Index (Bray and Curtis, 1957).

$$Djk = \frac{\sum_i |x_{ij} - x_{ik}|}{\sum_i (x_{ij} + x_{ik})}$$

Djk = Dissimilarity of stations j and k

x_{ij} = abundance of the ith species from station j

Stations were clustered using the group average technique and dendrograms of these results were plotted:

Both these measures are widely used to describe community structure in aquatic environments. Also, the Bray-Curtis Index is sensitive to changes in abundance of species as well as changes in species composition between sites (Day, et al. 1971). Clustering of data using the group average technique leads to more accurate although less distinct groups than other commonly used techniques (Walker, 1974).

RESULTS AND DISCUSSION

BIOLOGICAL CHARACTERIZATION

Cosmopolis

Annelid worms comprised 95% of the benthic invertebrate community at the 2.14 station during all seasons except winter. In winter, insect larvae made up 12% of all individuals (Mean abundance was 1,212 per m^2) (Table 2, Fig. 2: OT = other, which consisted entirely of insect larvae in winter). Community structure throughout the year was dominated by the brackish water sabellid polychaeta Manayunkia aesturina and oligochaetes. These two groups formed the entire annelid population. Manayunkia was most abundant in autumn, with a mean density of 37,273 per m^2. Oligochaetes were most abundant in spring, with a mean density of 15,000 per m^2. Overall invertebrate abundance was highest in autumn, with a mean of 51,667 organisms per m^2. Annelids accounted for 96% (49,394 individuals) of the total number of organisms. The lowest mean abundance of invertebrates was in winter, with 9,848 organisms per m^2 (Appendix C, Table 1; Figure 3).

Manayunkia aesturarina and oligochaetes dominated the 1.22 meter elevation community, except in autumn when Manayunkia and the amphipod Corophium spinicorne were predominant (Table 2, Figure 4).

Table 2. Composition, by percent, of total abundance of benthic invertebrate community by season and station at Cosmopolis, Grays Harbor, Washington, 1980-81.

	STATIONS											
	MLLW				1.22 [1]				2.14 [1]			
Organism	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Corophium spinicorne	55	45	69	73	--	9	24	--	--	0	--	0
Gnorimosphaeroma luteum	--	--	0	--	--	5	6	--	0	--	--	0
Manayunkia aestuarina	8	--	--	--	75	64	61	83	50	70	72	42
Oligochaeta	--	--	--	6	16	20	--	10	49	29	23	46
Polydora hamata	30	47	25	14	--	--	5	--	0	0	0	0
All else	7	8	6	7	9	2	4	7	1	1	5	12
TOTAL STATION ABUNDANCE [2]	16,364	55,000	28,030	12,727	21,212	45,303	12,576	35,455	30,758	26,264	51,667	9,848

	STATIONS							
	Bottom				Side			
Balanus sp.	0	7	0	0	--	5	0	8
Corophium spinicorne	--	26	--	74	89	78	88	91
Oligochaeta	96	35	97	0	--	--	--	0
Polydora hamata	0	7	0	19	8	12	5	--
All else	4	25	3	7	3	5	7	1
TOTAL STATION ABUNDANCE	40,405	2,300	40,590	15,800	40,180	35,250	44,000	39,600

1 Elevation in meters relative to mean lower low water ; Bottom and Side of the navigation channel
2 Mean numbers of individuals per m^2.

"--" = less than 5 percent; "0" = none present

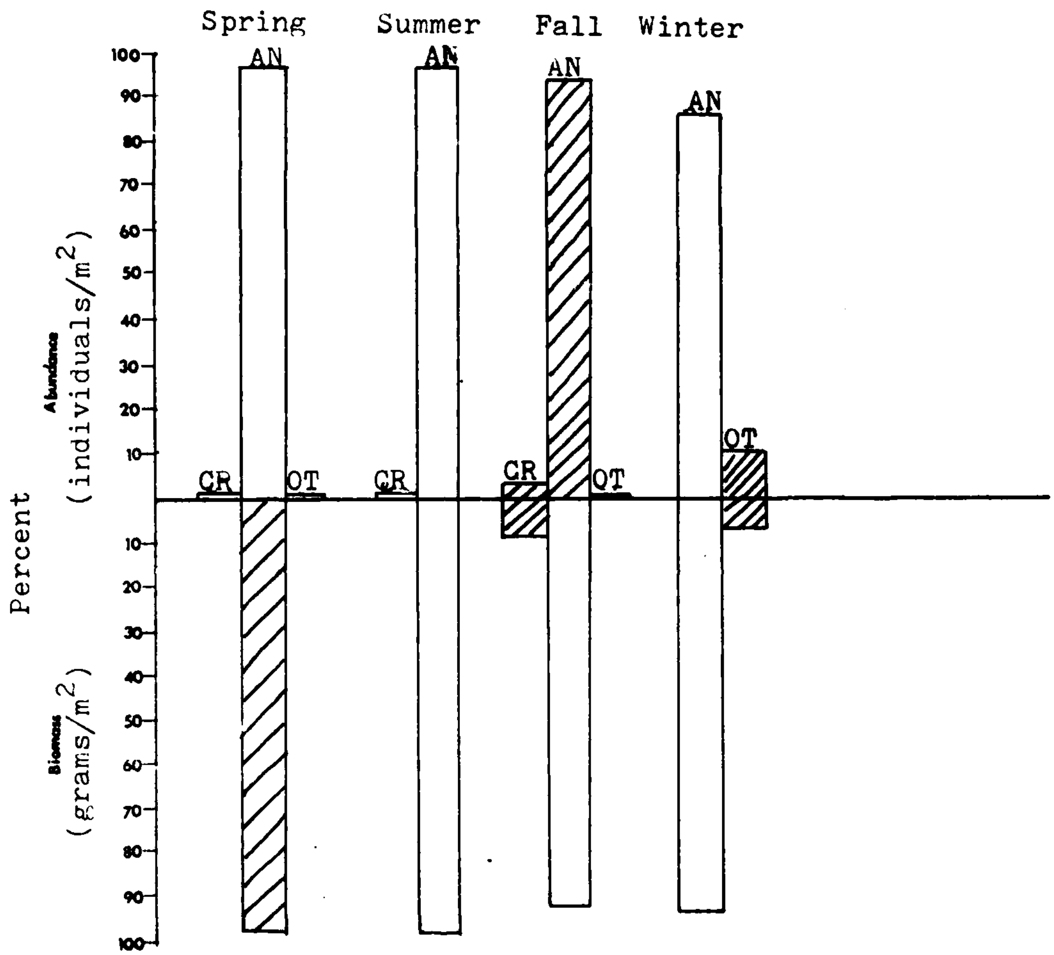

Figure 2. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 2.14 m station, Cosmopolis, Grays Harbor, Washington, 1980-81.

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[1] CR = Crustaceans, AN = Annelids, CL = Clams, OT = Other

NOTE: **Crosshatching indicates highest abundance or biomass during the year.**

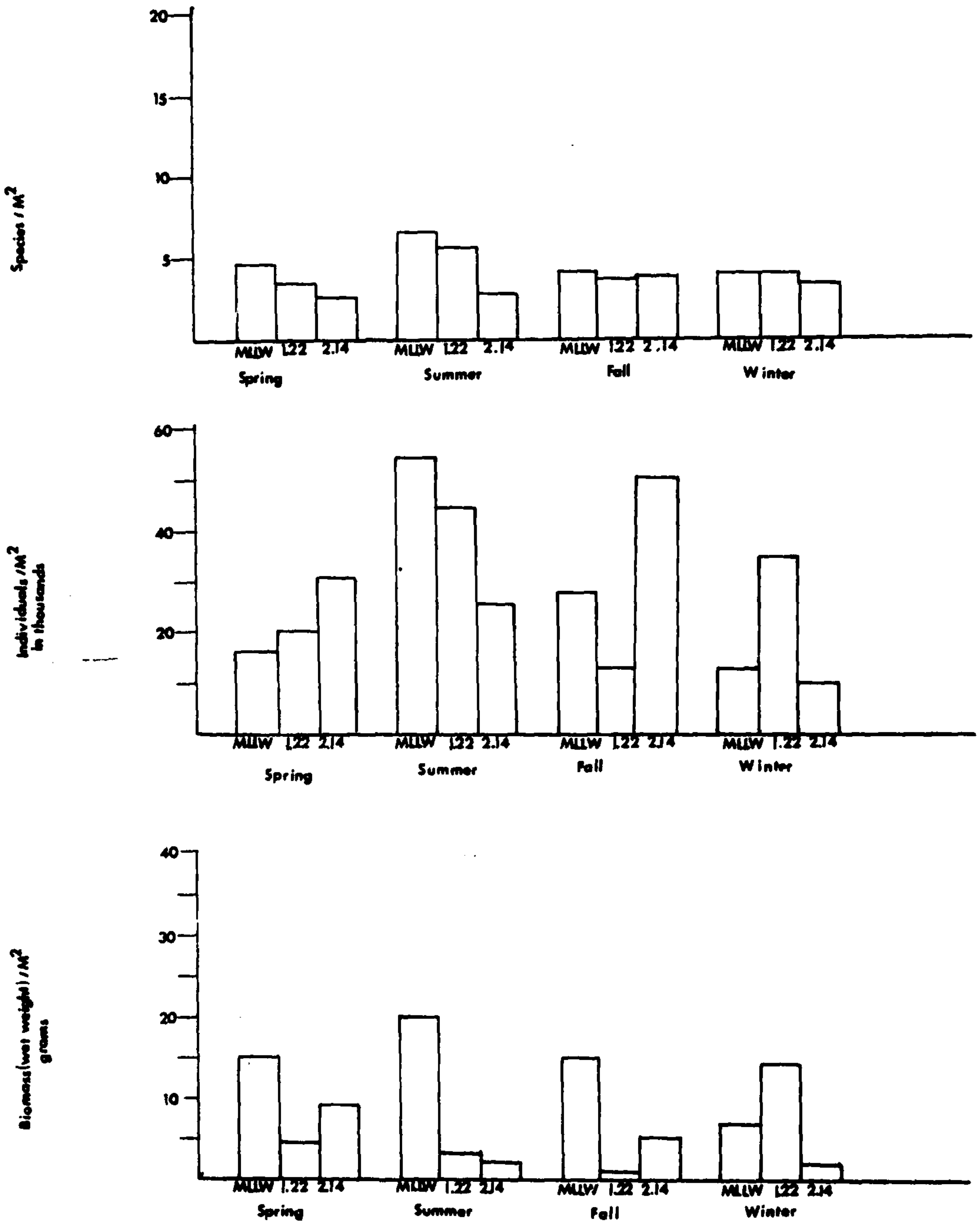

Figure 3. Mean number of species, individuals, and biomass by station, (in meters relative to MLLW) seasonally at Cosmopolis, Grays Harbor, 1980-81.

In autumn, the spionid polychaete _Polydora hamata_ and the isopod _Gnorimosphaeroma luteum_ each comprised 5% or more of the total community abundance. _Manayunkia_ were most abundant in winter with a mean of 29,546 individuals per m^2. Oligochaete were most abundant in summer with a mean density of 9,091 per m^2. Overall invertebrate abundance was highest in summer with a mean of 45,303 organisms per m^2. Annelids accounted for 38,940 of these individuals, which was the highest annelid abundance for the year Overall invertebrate abundance was lowest in autumn, when there were 12,576 organisms per m^2 (Fig. 4).

Community structure at MLLW was dominated by the amphipod _Corophium spinicorne_ and polychaete _Polydora hamata_ (Table 2, Fig. 5). _Corophium_ was the most abundant of these two species in all seasons except summer. Both _Corophium_ and _Polydora_ reached population peaks in summer, when _Corophium_ mean density was 24,546 per m^2 and _Polydora_ mean density was 26,061 per m^2. Crustacean (mainly _Corophium_) and annelid (mainly _Polydora_) populations are extremely important throughout the year at this station (Fig. 5). Overall invertebrate abundance was highest in summer with a mean of 55,000 invertebrates per m^2 and the lowest in winter, with 12,727 invertebrates per m^2 (Fig. 4).

The channel side station community was dominated by large numbers of the amphipod _Corophium spinicorne_ (Fig. 6). The next 2 most prevalent organisms were the polychaete _Polydora hamata_,

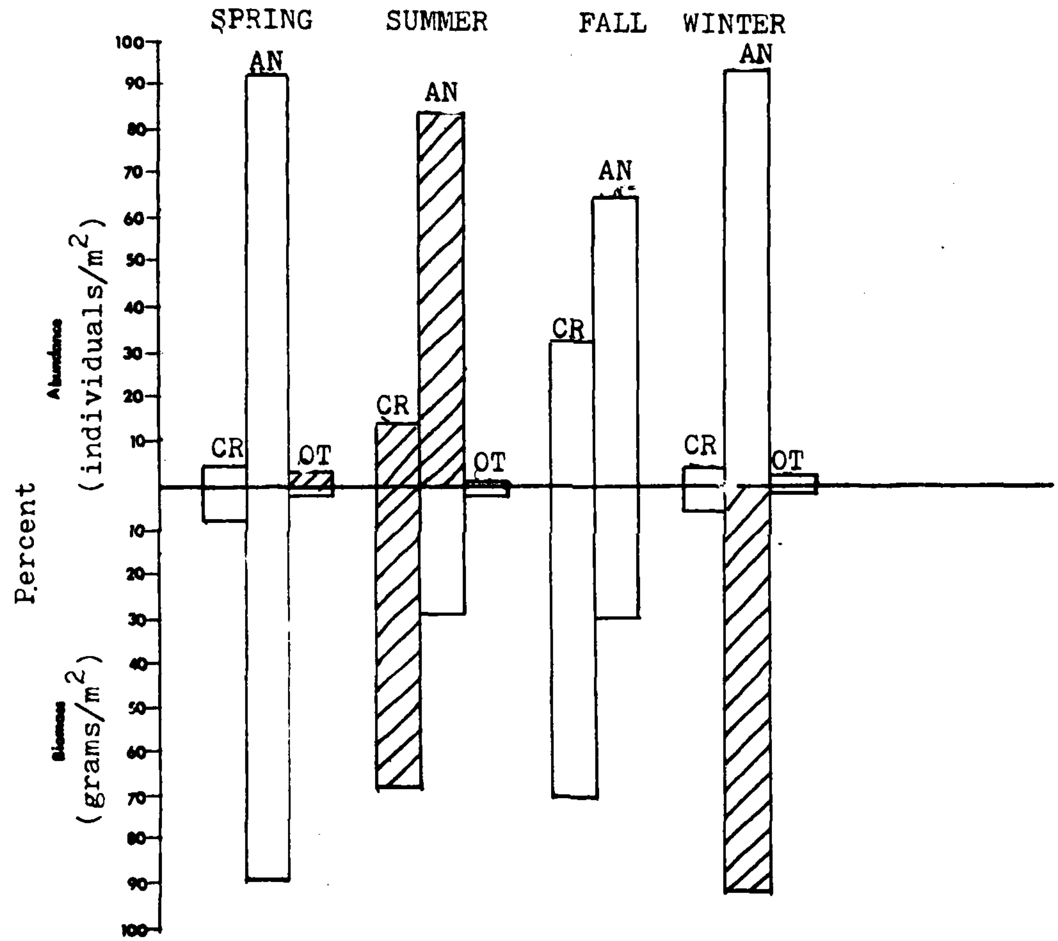

Figure 4. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 1.22 m station, Cosmopolis, Grays Harbor, Washington, 1980-81.

[1] See Figure 2 for footnote.

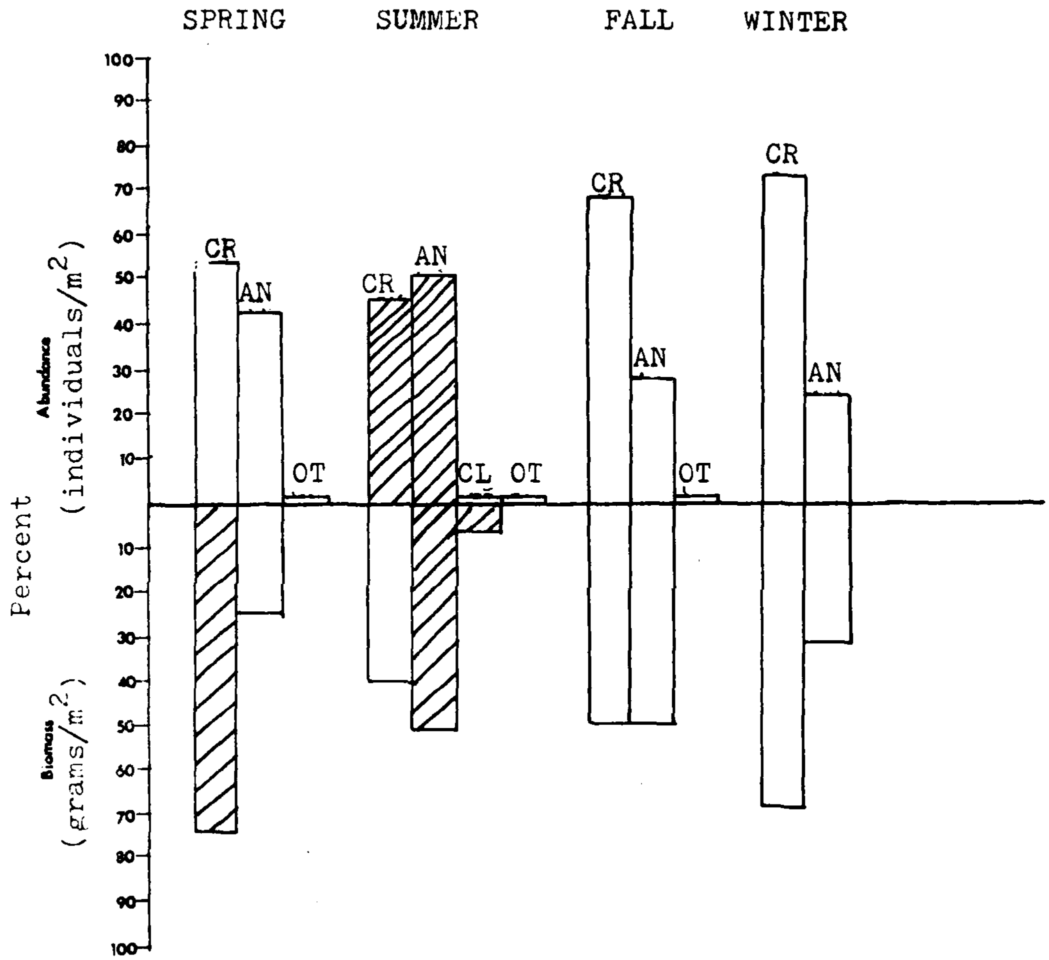

Figure 5. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the MLLW station, Cosmopolis, Grays Harbor, Washington, 1980-81.

[1] See Figure 2 for footnote.

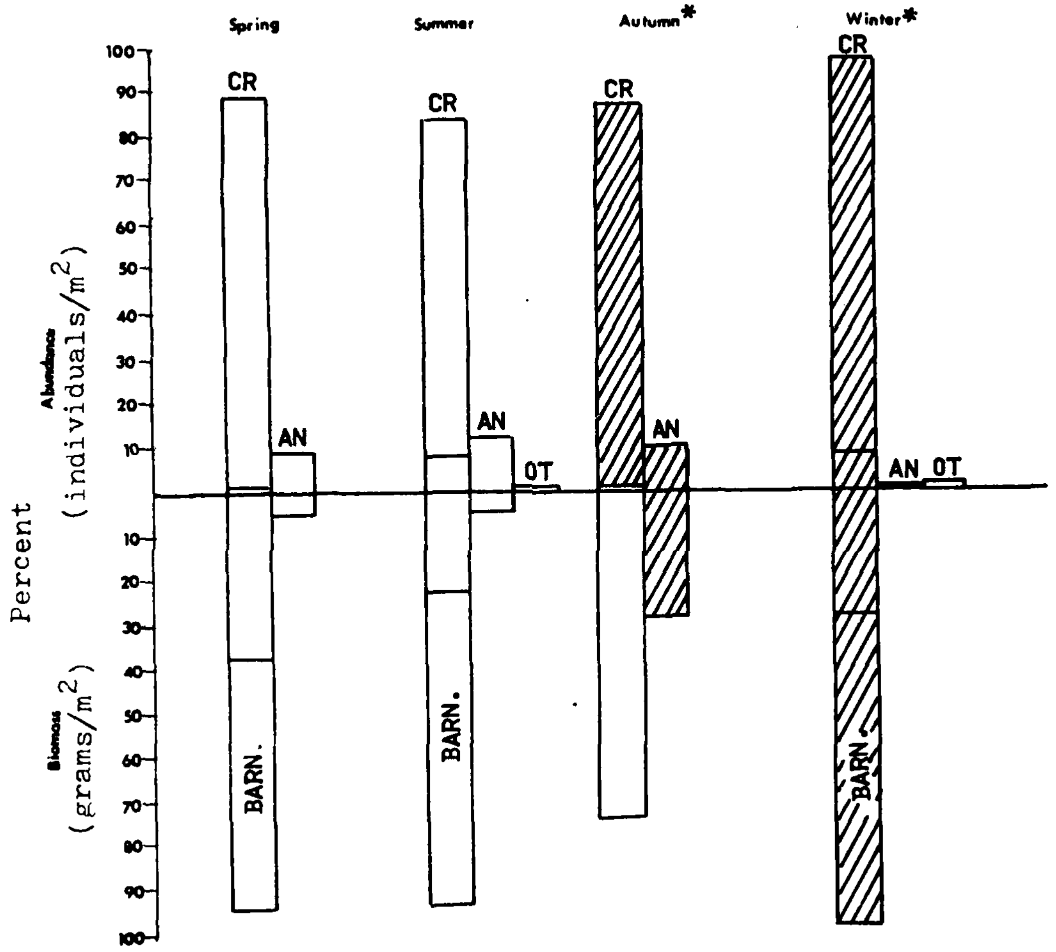

Figure 6. Percent of invertebrate community occupied by five major categories[1] of invertebrates at the side of the navigation channel, Cosmopolis, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance/biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other, BARN = barnacle biomass. Upper portion of percent by number CR bars indicates <u>Corophium spinicorne</u> value.

* Data from one van Veen grab sample only.

and barnacles (Balanus sp.). In autumn the polychaete Hobsonia florida, accounted for 5% of the total abundance, and contributed significantly to community structure. Corophium spinicorne abundance was highest in autumn, with 38,800 individuals per m^2. Total numbers of crustaceans per m^2 were virtually equal in autumn and winter (Fig. 4). Barnacles were most abundant in winter with a mean density of 3,000 per m^2. Barnacles and Corophium together accounted for the peak crustacean abundance in winter (Table 2). Polydora hamata was most abundant in summer, with a mean density of 4,300 per m^2. Overall invertebrate abundance was highest in autumn, 44,000 organisms per m^2, and lowest in summer, 35,250 organisms per m^2 (Appendix C, Table 6: Fig. 6).

Oligochaetes were by far the most abundant organism in spring and autumn at the channel bottom station (Table 2, Figs. 7, 8). In summer, oligochaetes and Corophium spinicorne predominated. In winter, Corophium spinicorne and Polydora hamata were predominant.

During summer sampling, a large rock (33 x 25 cm) was caught in the van Veen grab sampler. A thick mat of Corophium tubes on this and other large rocks caught in the grab indicate such rocks probably constitute an important habitat for Corophium. Samples taken from the rock surface indicate Corophium spinicorne is more abundant at this station than indicated by the van Veen grabs used in the quantiative survey. Mean abundance from van Veen grab samples of Corophium was 600 per m^2. Samples from the rock surface yielded a mean abundance of 96,592 per m^2 (Table 3).

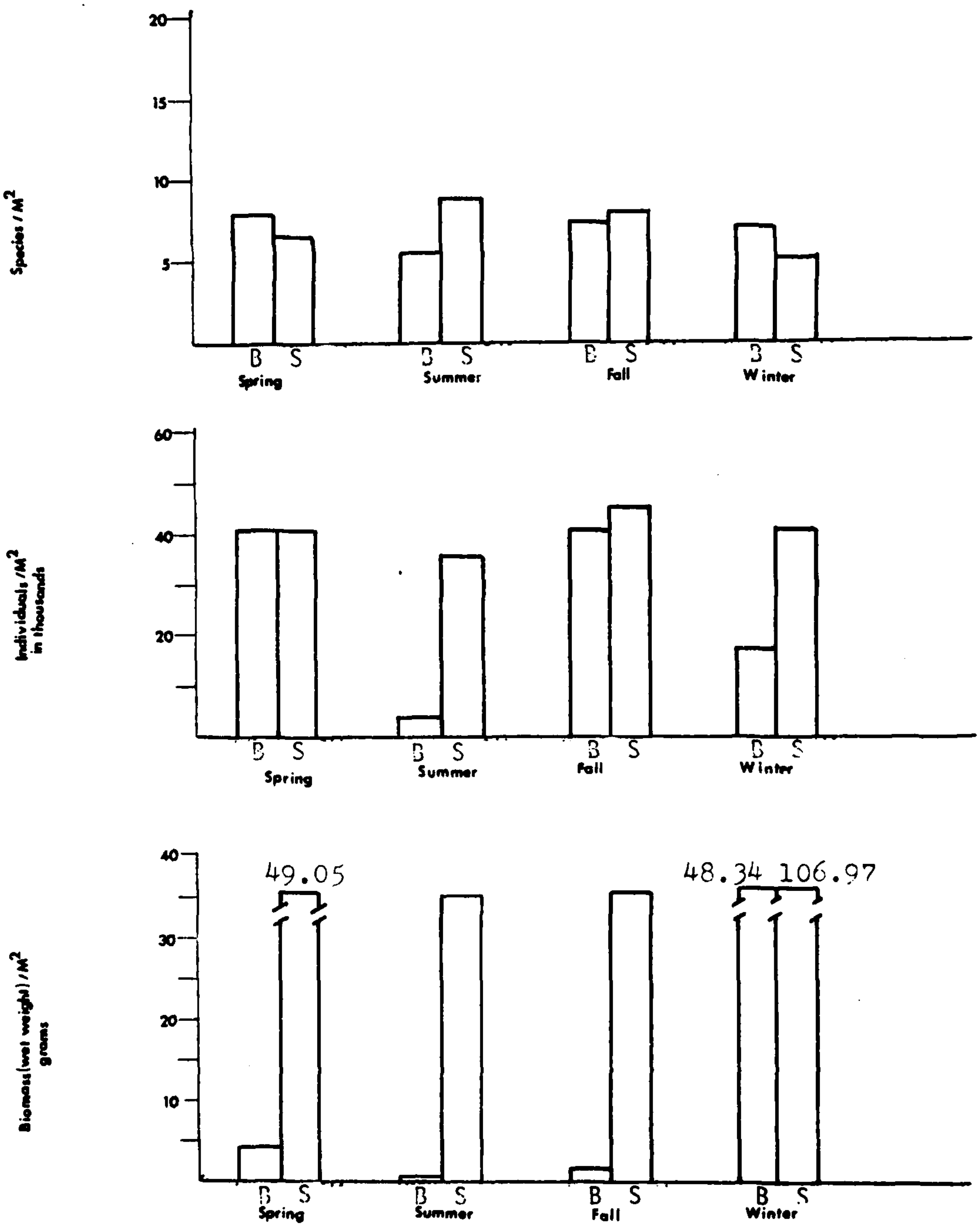

Figure 7. Mean number of species, individuals, and biomass per season by station at the bottom (B) and side (S) of the navigation channel, Cosmopolis, Grays Harbor, Washington, 1980-81.

Table 3. Abundance and biomass data from rock caught in van Veen grab sampler, Cosmopolis, Grays Harbor, Washington, 1980.

Station No. SS-1B-2, 8/27/1980, depth - 19.5 m.
Substrate: 13 x 10" rock

Bottom of navigation channel	ABUNDANCE ($\#/m^2$)			BIOMASS ($\#/m^2$)		
SURFACE OF ROCK	1	2	Mean	1	2	Mean
Crustacea	0	0	0	0	0	0
Corophium spinicorne	125,758	67,425	96,592	25.432	21.364	23.398
Annelida	0	0	0	0	0	0
Eteone longa	-0-	1,515	758	-0-	3.220	0
Oligochaeta	-0-	758	379	-0-	0	0
Polydora hamata	-0-	5,303	2,652	-0-	0	0
TOTAL Annelida	-0-	7,576	3,789	-0-	3.220	1.610
BOTTOM OF ROCK						
Crustacea	0	0	0	0	0	0
Corophium spinicorne	2,273	3,030	2,652	.614	.258	.436
Annelida	0	0	0	0	0	0
Nereis sp.	-0-	758	379	-0-	.273	.137

[1] Two samples from rock each 13.2 cm^2.

Numbers of Oligochaetes peaked in autumn when 39,390 per m^2 were observed. Numbers in spring were only slightly lower.

Corophium spinicorne abundance peaked in winter, with a density of 11,700 per m^2. This value is far less than that obtained from the rock surface samples collected during summer. Polydora hamata peak abundance occurred in winter, 3,000 per m^2. Overall invertebrate abundance was highest in autumn, 40,590 organisms per m^2, and lowest in summer, 2,300 organisms per m^2 (Appendix C, Table 6; Figs. 7, 8).

Cow Point

The polychaete worm, Manayunkia aestuarina, comprised 65-87% of the invertebrate community at the 2.14 m station. The remaining population was comprised mostly of the isopod, Gnorimosphaeroma luteum; amphipod, Corophium spinicorne; and Oligochaete worms (Table 4, Fig. 9). Highest numbers of invertebrates at this station occurred in summer when density was estimated at 240,910 organisms per m^2. Manayunkia aestuarina populations also peaked during summer with 216,819 worms/m^2 (Appendix G, Table 2). Lowest density, 45,303 organisms per m^2, occurred during spring.

At 1.22 meters numbers of Manayunkia and oligochaetes decreased, while numbers of Gnorimosphaeroma and Corophium spinicorne increased. The amphipod Eogammarus confervicolus was also an

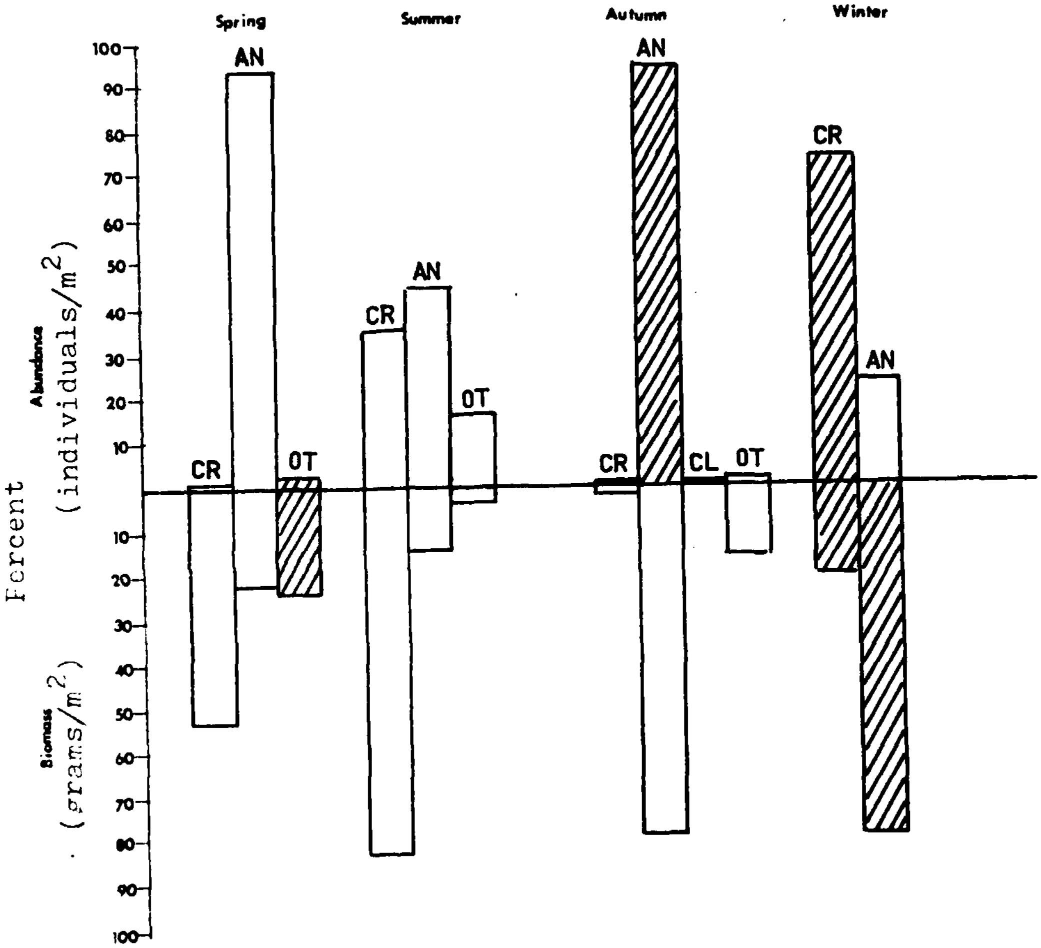

Figure 8. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the bottom of the navigation channel, Cosmopolis, Grays Harbor, Washington, 1980-81.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other. Patterned bars indicate peak abundance/biomass within that category for the year.

* Data from one van Veen grab sample only.

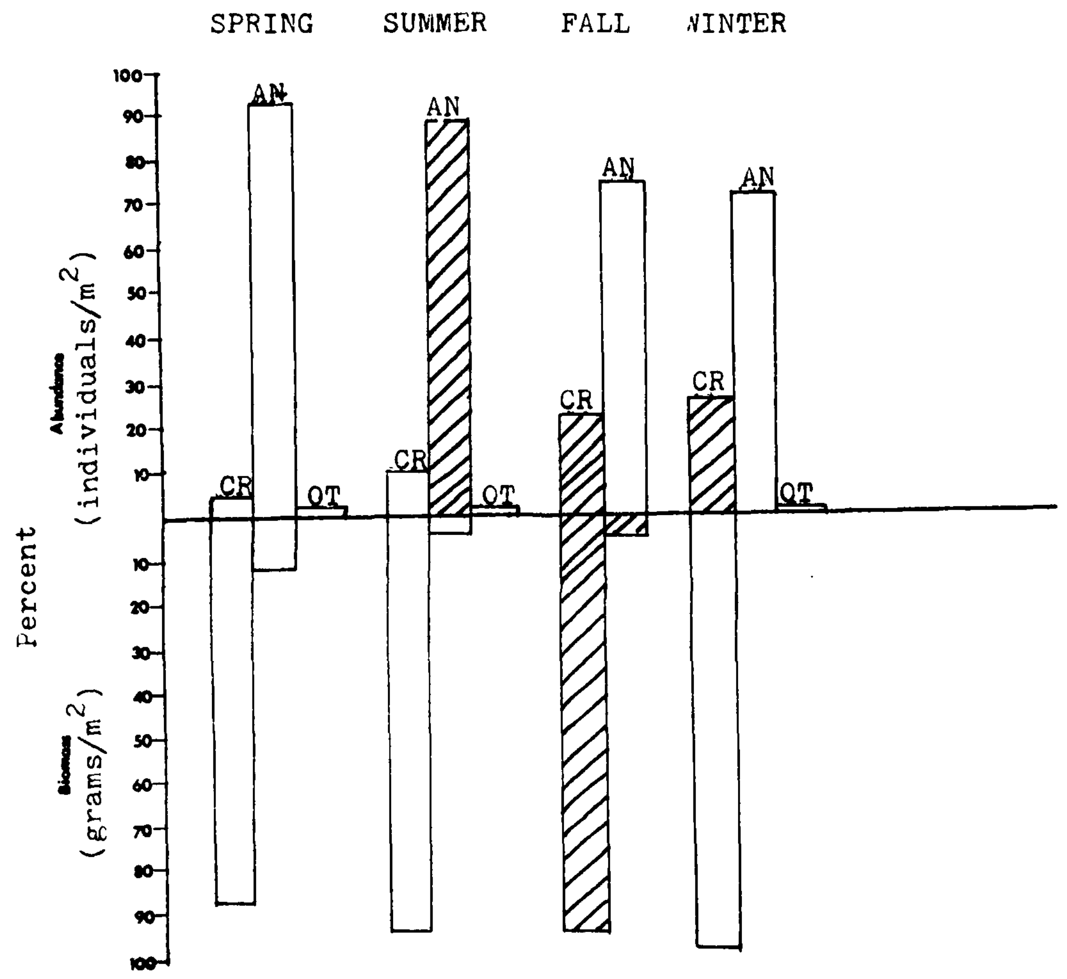

Figure 9. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 2.14 m station, Cow Point, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance biomass within that category for the year.

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[1] See Figure 2 for footnote.

important component of the community at this station (Table 4, Fig. 10). Crustacean abundance peaked at 12, 273 individuals per m^2 during summer. Gnorimosphaeroma abundnace peaked at this time, accounting for 44% of all crustaceas. Corophium spinicorne accounted for 25% of crustaceans at this time. Overall abundance was highest in summer with 15,152 individuals per m^2 and lowest in autumn with 4,697 individuals per m^2 (Fig. 11).

The most dramatic changes at the MLLW elevation was the presence of barnacles, Balanus sp. (Table 4). Other crustaceans were also predominant. These were: Corophium sp., especially Corophium spinicorne and Eogammarus confervicolus which were associated with the fine-grain substrate at this station. Also found in more fine-grain substrate were the polychaetes Streblospio benedicti and Hobsonia florida. Populations of both species peaked in autumn, as did annelids overall (Fig. 11). Highest overall invertebrate abundance was in summer with 88,940 invertebrates per m^2. Crustaceans represented 95% of overall community composition. Barnacles were the most abundant, 64,243 per m^2, crustacean accounting for 73% of all crustaceans at this station.

Oligachaete worms and the polychaete Streblospio bendiciti dominated the channel side community (Table 4). Corophium spinicorne and clams Macoma balthica, Macoma sp., and Mya arenaria were also present. Oligochaete worms were most

Table 4. Composition, by percent, of benthic invertebrate community by season and station at Cow Point, Grays Harbor, Washington, 1980-81.

	Stations											
	MLLW[1]				1.22				2.14			
Organism	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Balanus sp.	24	73	31	21	0	0	0	0	0	0	--	0
Corophium spinicorne	31	9	14	43	13	25	23	16	--	--	12	12
Corophium, all other sp.	9	13	--	6	--	--	--	7	--	--	--	--
Eogammarus confervicolus	10	--	--	--	43	11	19	9	0	--	--	--
Gnorimosphaeroma luteum	0	--	0	--	28	44	19	25	--	7	10	13
Hobsonia florida	--	--	12	6	--	--	6	--	0	--	--	--
Manayunkia aestuarina	--	0	6	0	--	13	13	24	74	87	65	66
Oligochaeta	15	--	6	11	8	--	--	5	21	--	10	6
Streblospio benedicti	0	0	19	6	0	0	0	0	0	0	0	0
All else	11	5	12	7	8	7	20	14	5	6	3	3
TOTAL STATION ABUNDANCE[2]	39,091	88,940	21,212	24,546	11,970	15,152	4,697	8,333	45,303	240,910	198,031	166,819

1 Elevation in meters relative to MLLW; Bottom and side of navigation channel

2 Mean numbers of individuals per m^2.

"--" = less than 5 percent

Blank = none present

Table 4 Continued.

Organism	Bottom				Side			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Corophium brevis	--	20	--	0	0	0	0	0
Corophium spinicorne	--	7	0	35	0	--	7	0
Leucon 1, unid	0	0	10	42	--	0	0	--
Macoma, balthica + sp.	--	--	5	12	17	--	0	--
Oligochaeta	--	--	--	--	72	72	29	59
Polydora ligni	76	35	10	0	0	0	0	0
Streblospio benedicti	--	22	53	0	6	10	58	29
All else	24	16	22	11	5	18	6	12
TOTAL STATION ABUNDANCE	1,780	12,705	8,905	130	770	1,450	2,750	690

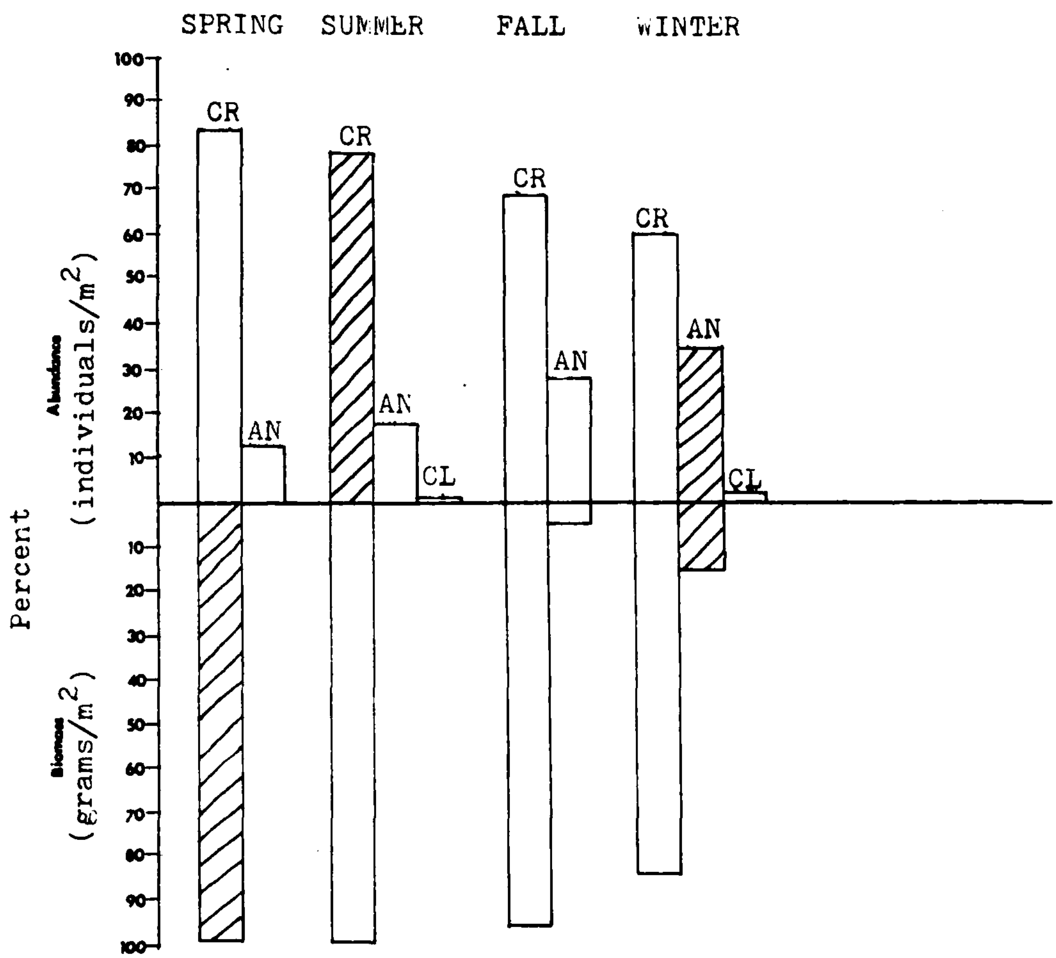

Figure 10. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 1.22 m station, Cow Point, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance biomass within that category for the year.

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[1] See Figure 2 for footnote.

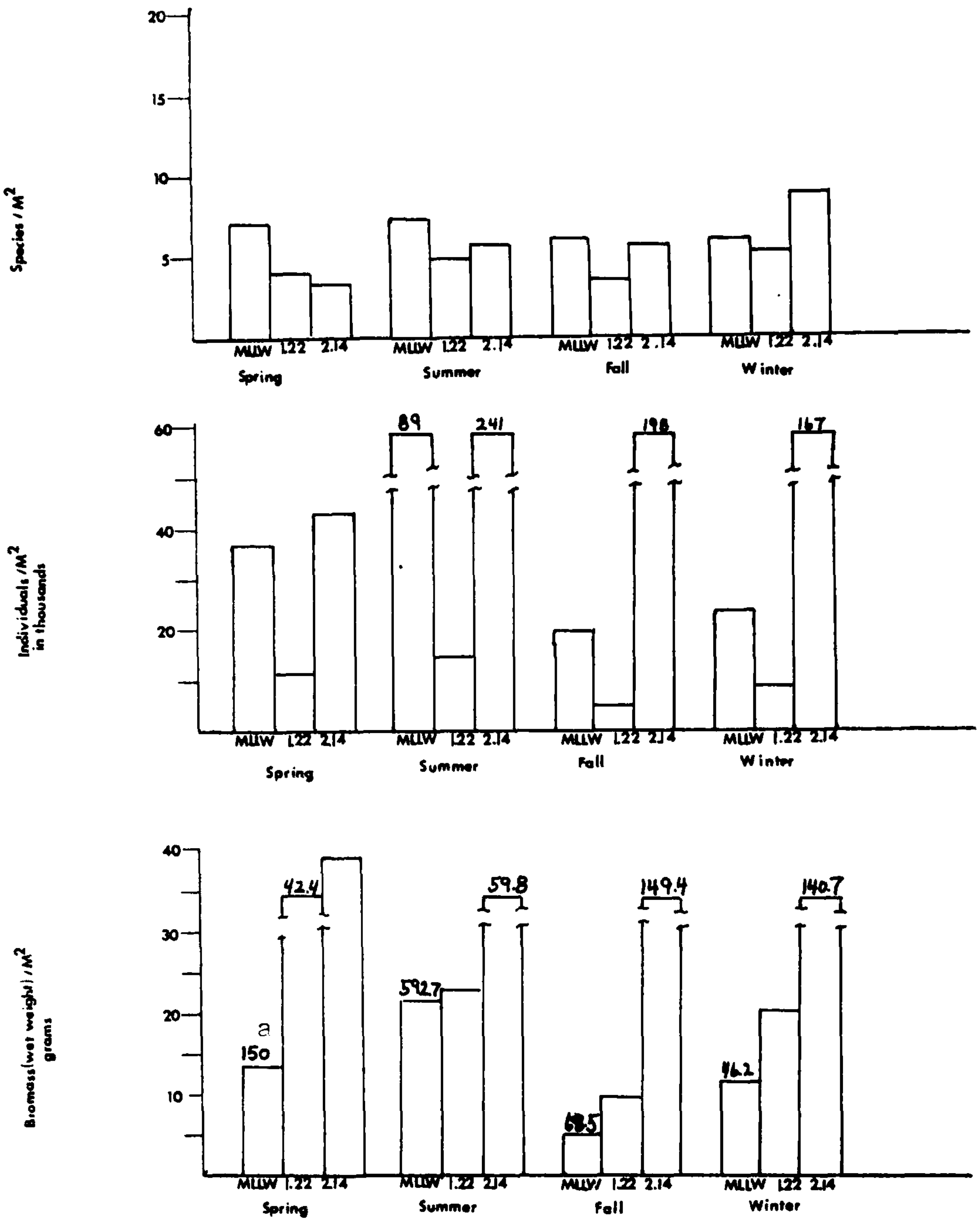

Figure 11. Mean number of species, individuals, and biomass per station (in meters relative MLLW), seasonally at Cow Point, Grays Harbor, Washington, 1980-81.

[a] Biomass value to add to include barnacles.

abundant in summer (1,050 per m^2) while Streblospio was most abundant in autumn (1,600 per m^2). The overall peak in abundance of annelids was in autumn with 2,400 individuals per m^2 (Fig. 12). Crustacean populations also peaked in autumn, with 250 individuals per m^2. Corophium spinicorne accounted for 80% of this population peak. Numbers of organisms were highest in autumn, 2,750 organisms per m^2 and lowest in winter, 690 organisms per m^2 (Fig. 13). Highest overall clam (mollusca) abundance occurred in spring with 130 individuals per m^2.

The spionid polychaetes Streblospio benedicti and Polydora ligni were the most abundant organisms at the channel bottom station (Table 4). Corophium brevis, Corophium spinicorne, Corophium salmonis and Eogammarus sp. were the most common crustaceans. The clams Macoma balthica, Macoma sp., and Mya arenaria were most abundant in autumn with 850 individuals per m^2 (Appendix C, Table 7). The relative abundance of clams was highest in winter. This was largely due to lower abundance of non-molluscan organisms (Fig. 14). Abundance of Streblospio peaked in autumn with 4,700 individuals per m^2. Peak Polydora ligni abundance occurred in summer with 4,400 individuals per m^2. Overall annelid abundance was highest in summer (7,650 individuals per m^2). Corophium brevis was most abundant in summer with 2,550 individuals per m^2. Invertebrate abundance was highest in summer, 12,705 organisms per m^2, and lowest in winter, 130 organisms per m^2 (Fig. 15).

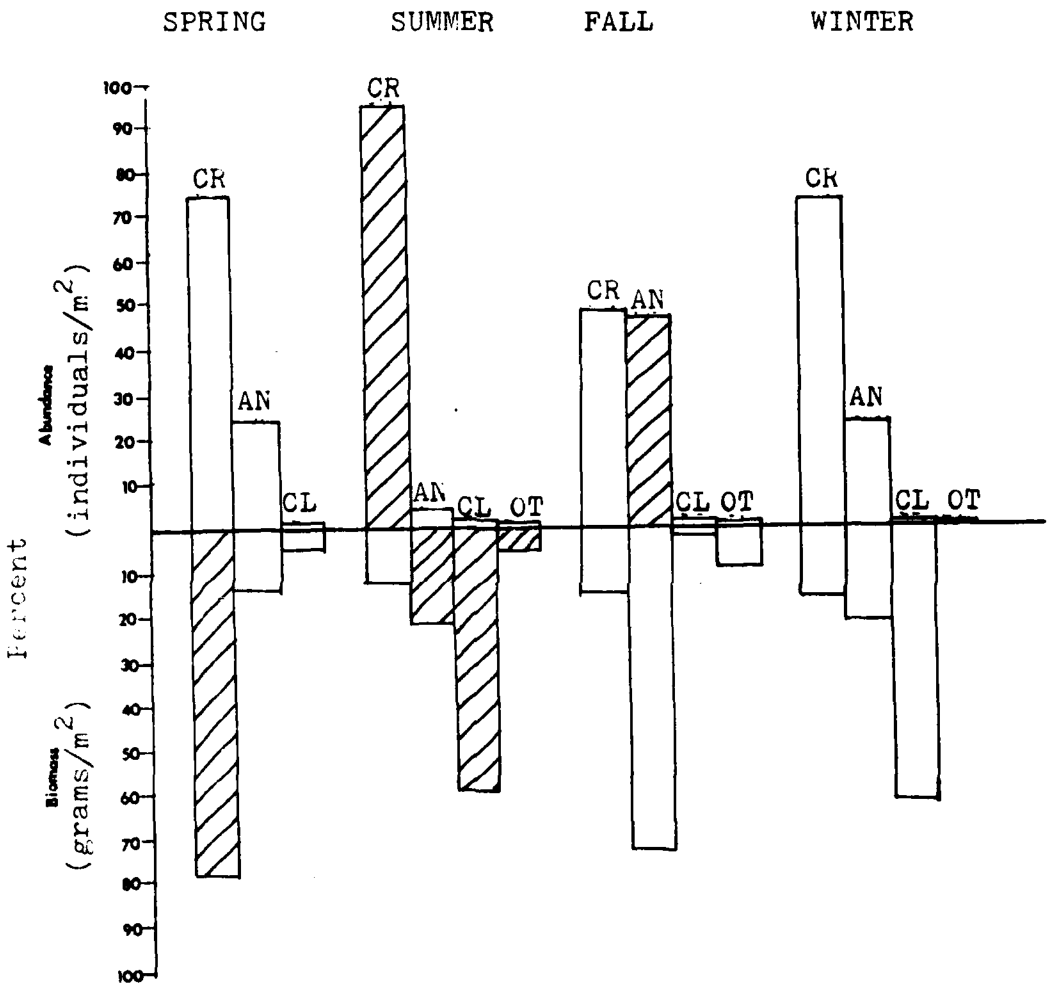

Figure 12. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the MLLW station, Cow Point, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

[1] See Figure 2 for footnote.

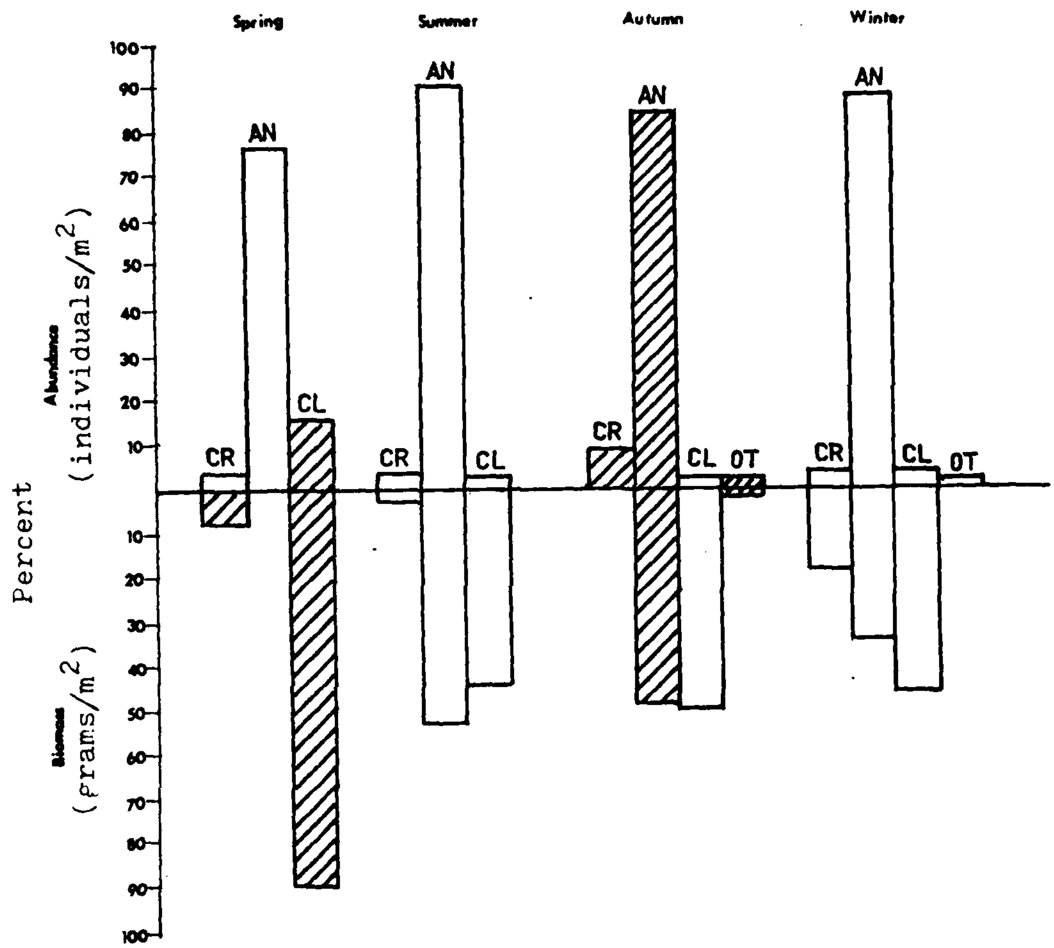

Figure 13. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the side of the navigation channel, Cow Point, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other

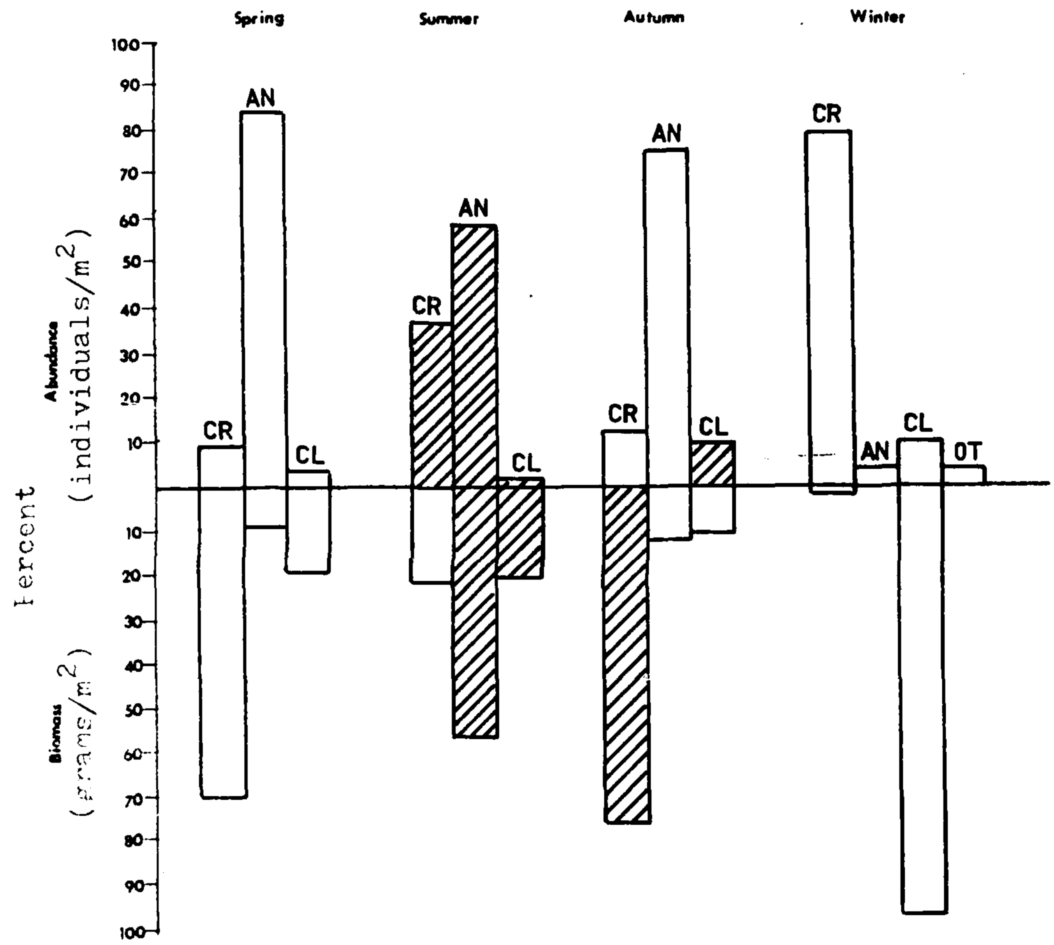

Figure 14. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the bottom of the navigation channel, Cow Point, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other

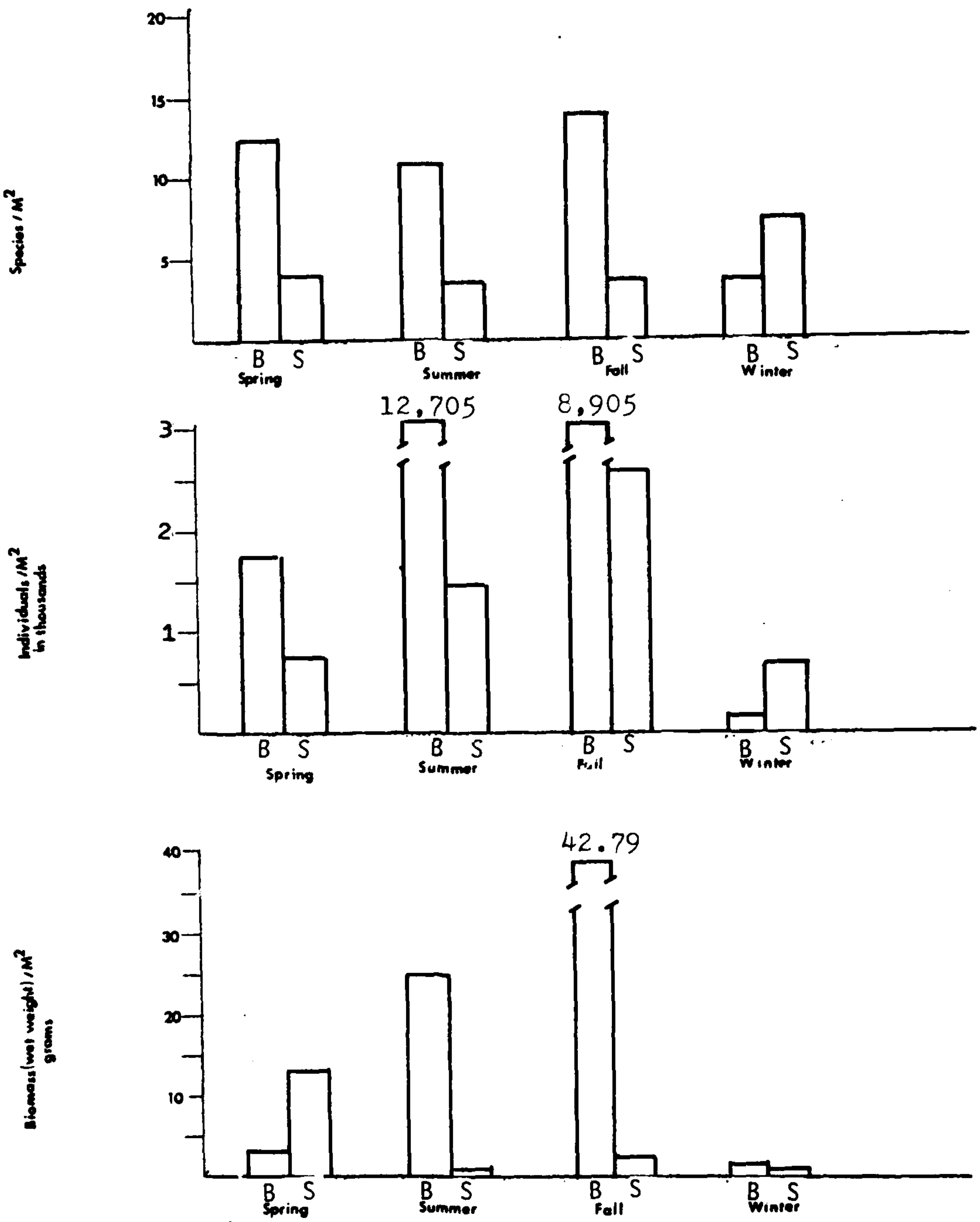

Figure 15. Mean number of species, individuals, and biomass at the bottom (B) and side (S) stations of the navigation channel, at Cow Point, Grays Harbor, Washington, 1980-81.

Marsh Establishment

Manayunkia aestuarina and *Corophium salmonis* were the most abundant organisms at the 2.14 meter station. Other important annelids included *Hobsonia florida* and oligochaete worms (Table 5). Other crustaceans included a tanaid (*Tanais* sp.), the amphipod *Eogammarus confervicolus*, and *Gnorimosphaeroma luteum*. *Manayunkia* was most abundant in winter with a density of 53,031 individuals per m^2. Both annelid and total invertebrate abundance was largely determined by the abundance of *Manayunkia*. Annelid and total invertebrate abundance were highest in winter (Appendix C, Table 3; Fig. 16). *Corophium salmonis* was most abundant in autumn with a density of 10,000 individuals per m^2. *Corophium salmonis* was more abundant at the 2.14 meter station than any other station at Site M. Overall invertebrate abundance was lowest in spring with 27,121 organisms per m^2 (Figure 17).

Manayunkia aestuarina was by far the most abundant organism at 1.22 meters. *Streblospio benedicti* and *Corophium salmonis* were next most abundant (Table 5). This station also had dense populations of the polychaetes *Heteromastus filiformis* and *Eteone longa*. Both *Manayunkia* and *Streblospio* were more abundant at the 1.22 meter station than at any other station at Site M. In spring, *Manayunkia* density peaked at 90,910 individuals per m^2.. *Streblospio* reached a peak density of 5,606 per m^2 individuals in winter. Annelid populations were greatest in spring (Fig. 18). Invertebrate abundance was greatest in spring with 102,576 organisms per m^2, corres-

Table 5. Composition, by percent, of benthic invertebrate community by season and station at the Marsh Establishment Site, Grays Harbor, Washington, 1980-81.

	Stations											
	MLLW[1]				1.22				2.14			
Organism	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Balanus sp.	12	52	0	0	0	0	--	0	0	0	0	0
Corophium salmonis	0	--	20	6	--	10	8	--	13	16	17	9
Corophium spinicorne	5	8	0	7	--	0	--	0	0	0	0	--
Hobsonia florida	10	14	27	43	--	0	--	--	13	--	--	7
Leucon 1, unid.	0	0	0	0	--	0	9	0	0	0	--	0
Macoma balthica	19	--	0	10	--	0	--	0	--	0	0	--
Manayunkia aestuarina	19	--	13	10	89	76	43	80	63	81	70	76
Oligochaeta	12	--	7	--	--	--	--	--	--	0	7	--
Streblospio benedicti	--	--	0	0	--	5	23	9	--	--	0	--
All else	23	26	33	24	11	9	17	11	11	3	6	8
TOTAL STATION ABUNDANCE[2]	6,364	17,576	2,273	10,455	102,576	54,849	20,000	64,697	27,121	32,007	60,000	69,394

[1] Elevation in meters relative to mean lower low water (MLLW).

[2] Mean numbers of individuals per m^2.

"--" = less than 5 percent; Blank = none present.

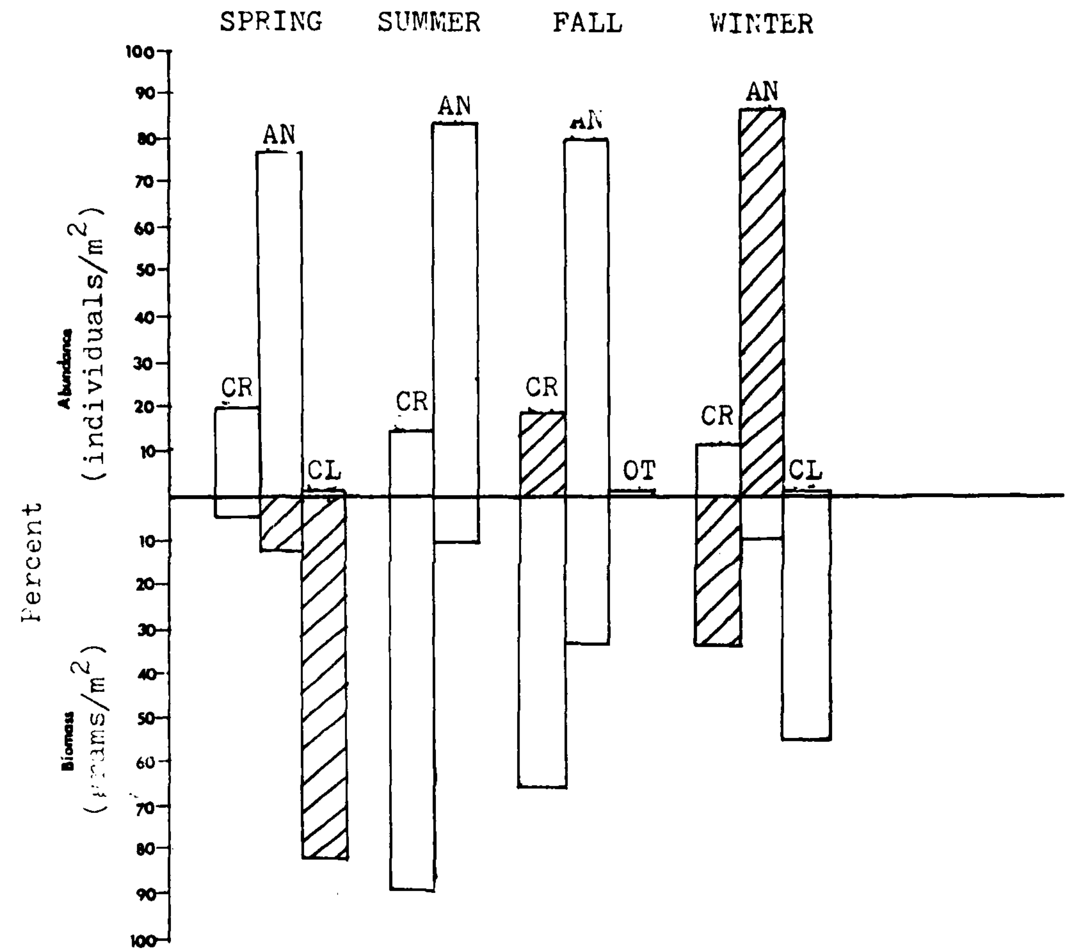

Figure 16. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 2.14 m station, Marsh Establishment site, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance biomass within that category for the year.

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[1] See Figure 14 for footnote.

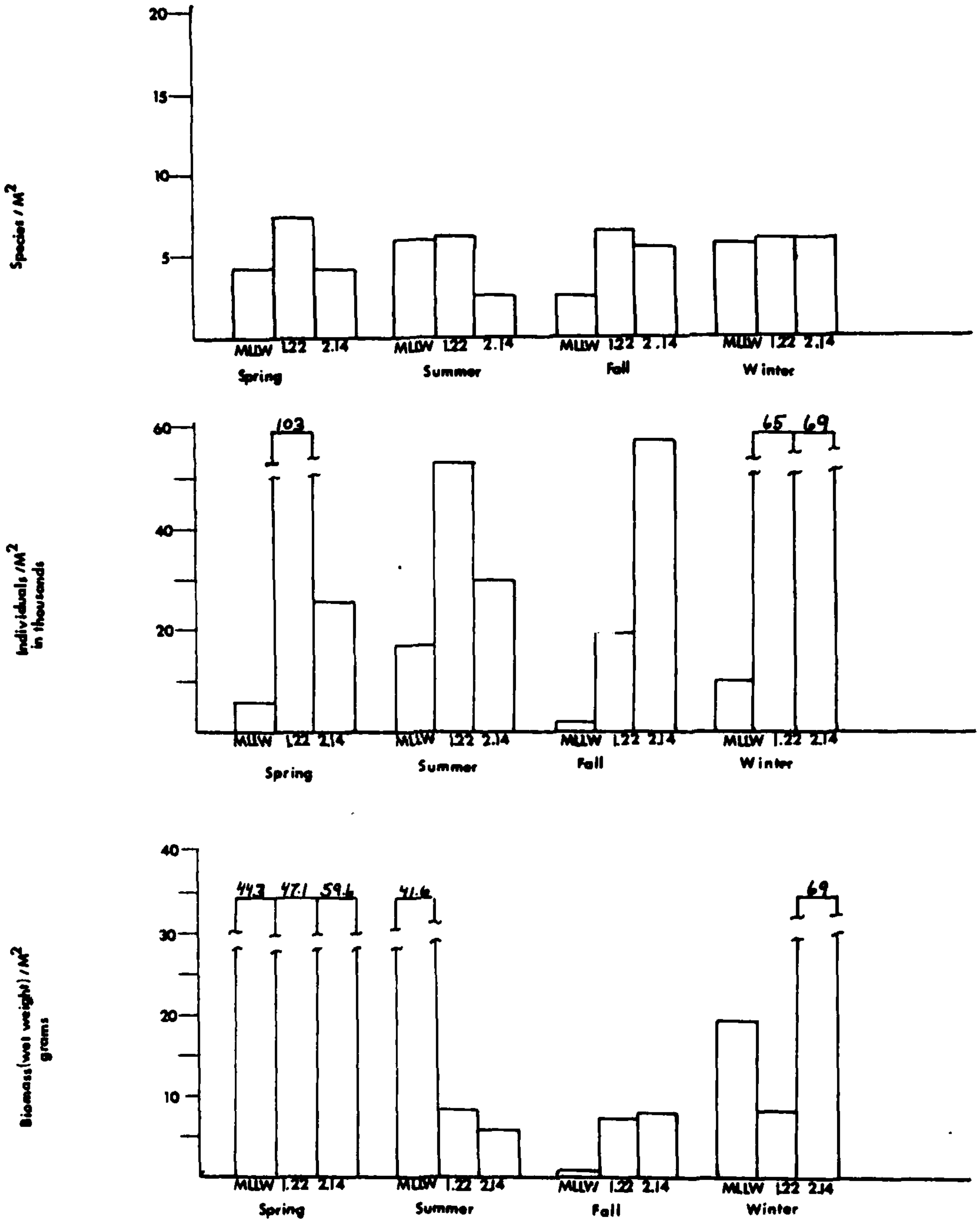

Figure 17. Mean number of species, individuals, and biomass per station (in meters relative to MLLW), seasonally at the Marsh Establishment site, Grays Harbor, Washington, 1980-81.

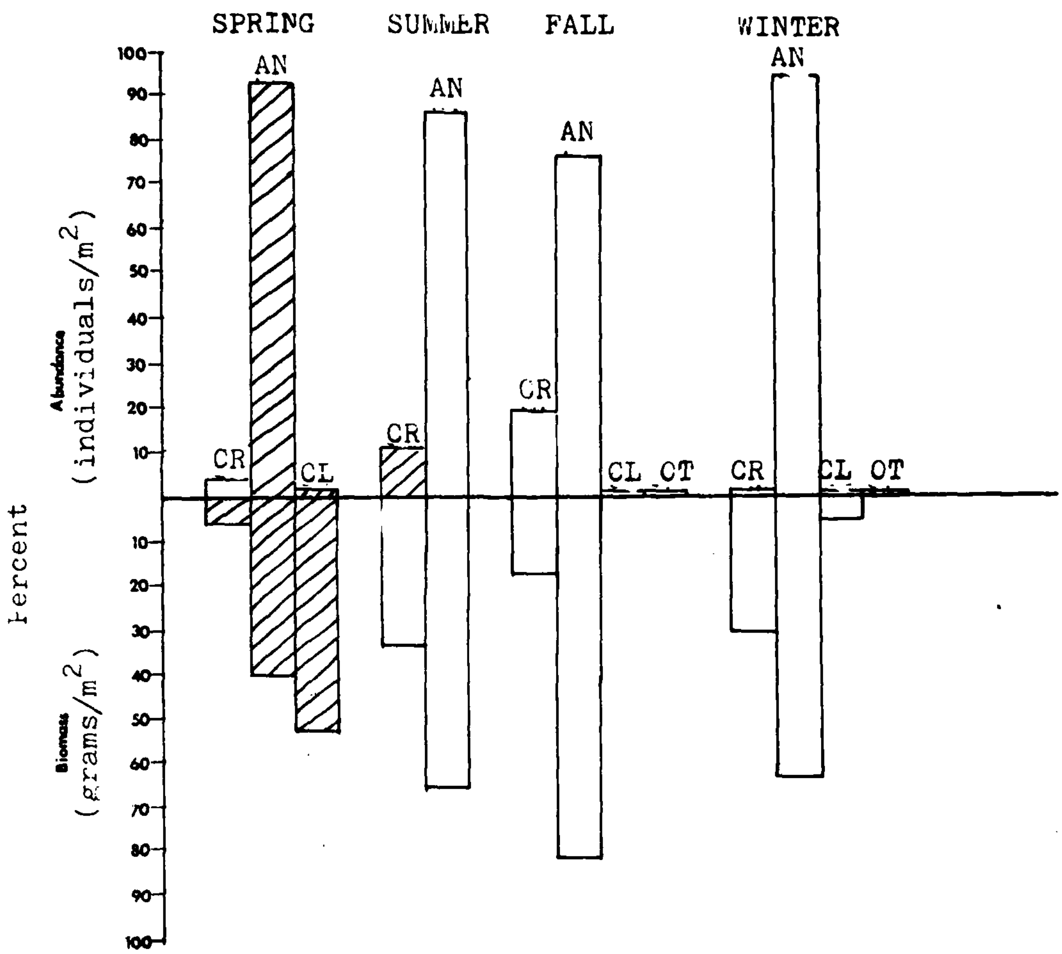

Figure 18. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 1.22 m station, Marsh Establishment site, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

[1] See Figure 14 for footnote.

ponding to the peak in _Manayunkia_ abundance , and lowest in autumn with 20,000 organisms per m^2 (Appendix C, Table 3; Fig. 17).

During summer high numbers of barnacles (_Balanus_ sp.), 9,091 individuals per m^2, were present at the MLLW station. Barnacles accounted for 76% of all crustaceans during summer (Fig. 19). Barnacles were the most abundant organism at MLLW station for the year. However, this is based solely on their summer populations. _Hobsonia florida_, an ampharetid polychaete, occurred consistently throughout all seasons at this station. Populations peaked in winter (Table 5).

Other less prominent organisms included _Manayunkia aestuarina_, _Macoma balthica_ and _Corophium spinicorne_. _Corophium spinicorne_ was restricted almost entirely to the MLLW station at site M.

The highest density of organisms, 17,576 per m^2, occurred at this station during summer. Lowest density was 2,273 organisms per m^2 in autumn (Appendix C, Table 3; Fig. 17).

Marsh Control

In order of relative importance, the following organisms were found at the 2.14 m station: _Manayunkia aestuarina_, _Corophium salmonis_, _Streblospio benedicti_, _Polydora kempi japonica_ and _Eteone longa_ (Table 6). Annelids were the most abundant faunal group contributing up to 97% of all organisms at this station (Fig. 20). _Corophium salmonis_ was most abundant in autumn with 34,697 individuals per m^2. The 2.14 meter station had by far

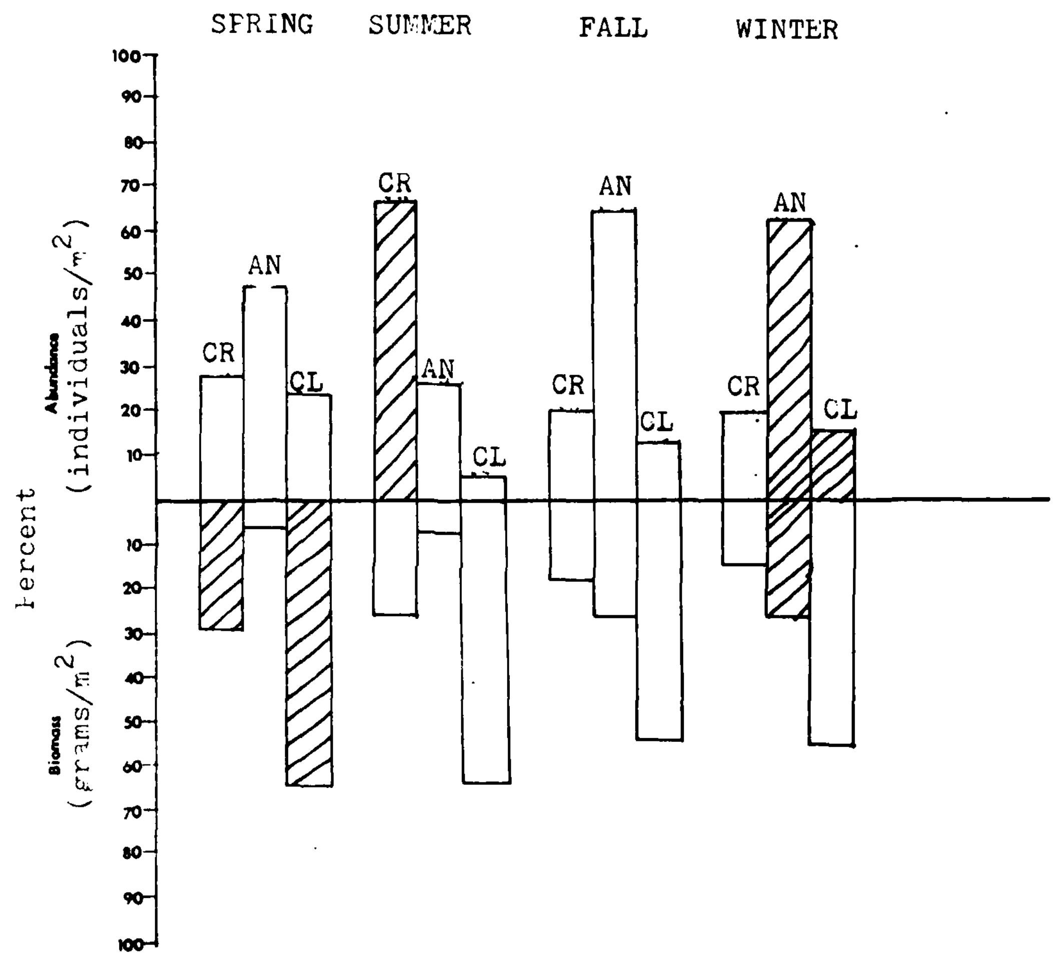

Figure 19. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the MLLW station, Marsh Establishment site, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] See Figure 14 for footnote.

Table 6. Composition, by percent, of benthic invertebrate community by season and station at the Marsh Control Site, Grays Harbor, Washington, 1980-81.

	Stations											
	MLLW[1]				1.22				2.14			
Organism	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Corophium salmonis	0	--	8	6	0	9	9	5	--	35	31	12
Corophium spinicorne	0	16	0	0	0	--	0	0	0	--	0	0
Leucon 1, unid.	26	0	53	25	17	0	27	29	--	0	--	--
Macoma balthica	22	--	--	19	13	8	0	9	--	--	--	--
Manayunki aestuarnia	15	20	9	0	6	--	--	13	81	28	54	47
Oligochaeta	26	12	0	31	--	0	--	--	--	--	0	--
Polydora kempi japonica	0	8	0	0	9	5	--	0	4	--	--	--
Streblospio benedicti	7	16	19	19	49	58	49	34	10	22	9	30
All else	4	28	11	0	6	20	15	10	5	15	6	11
TOTAL STATION[2] ABUNDANCE	4,091	3,788	11,364	2,424	7,121	11,667	20,152	13,182	85,910	20,152	113,334	49,546

[1] Elevation in meters relative to mean lower low water (MLLW).

[2] Mean numbers of individuals per m^2.

"--" = less than 5 percent; Blank = none present.

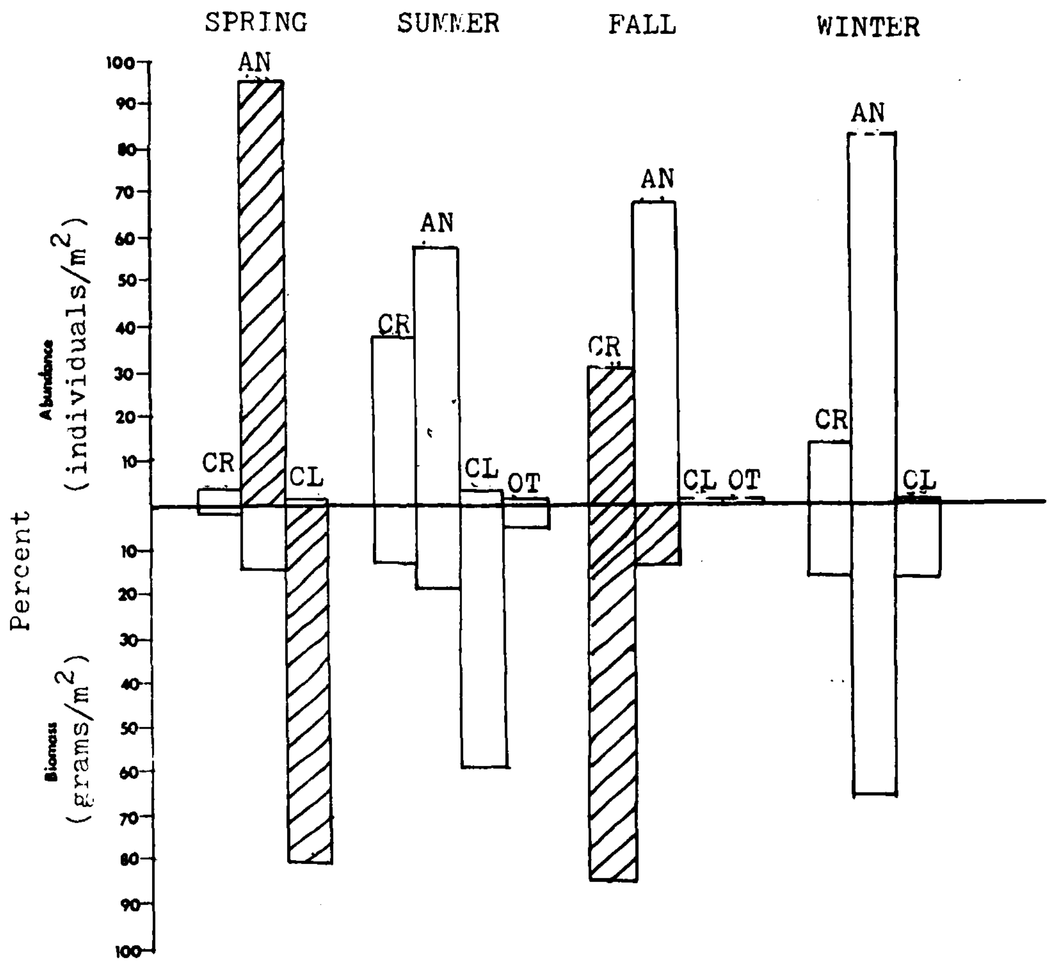

Figure 20. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 2.11 m station, Marsh Control site, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] See Figure 14 for footnote.

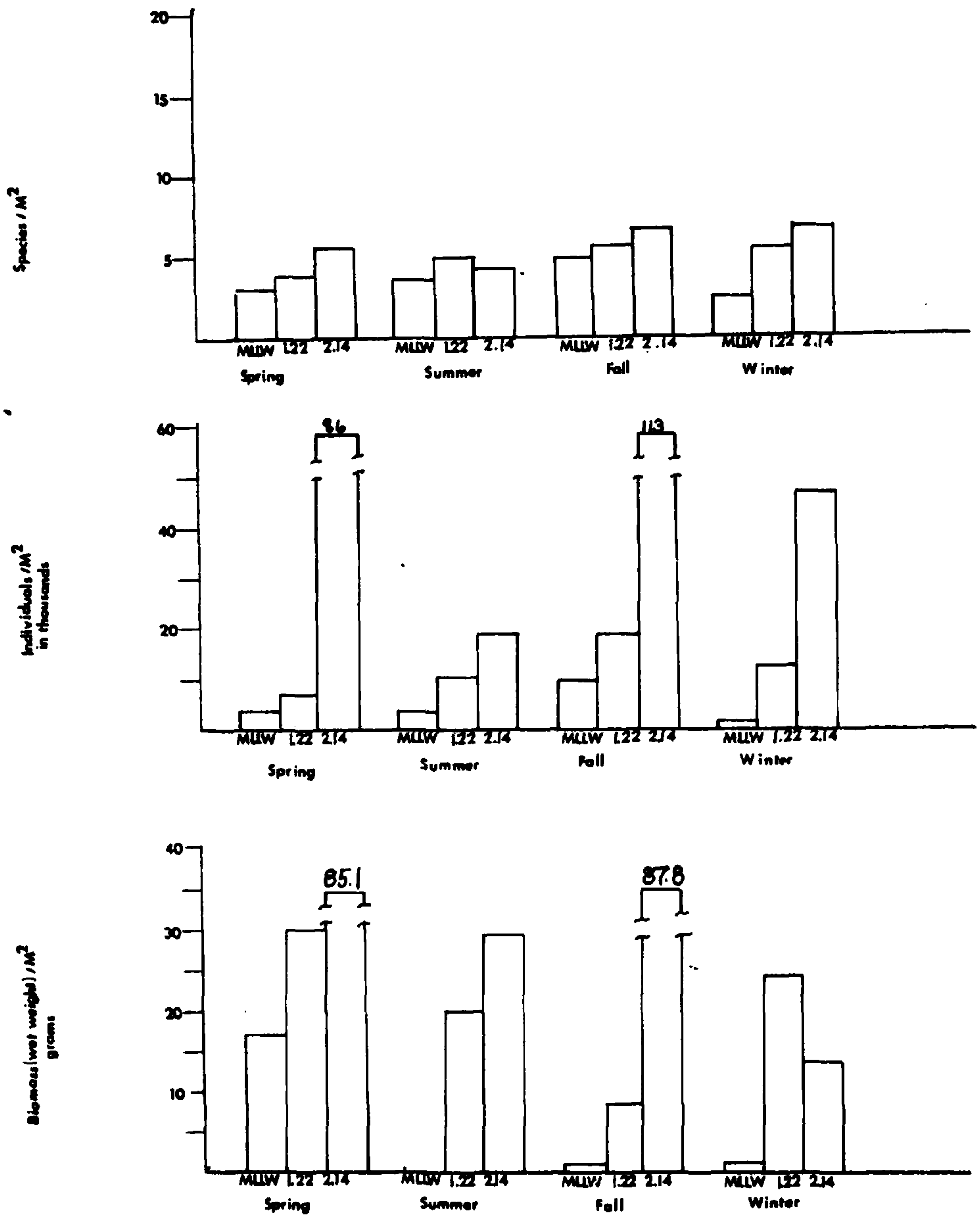

Figure 21. Mean number of species, individuals, and biomass per station (in meters relative to MLLW), seasonally at the Marsh Control site, Grays Harbor, Washington, 1980-81.

more Corophium than any other station at site MC. Streblospio was most abundant in winter with 15,000 individuals per m^2. Polydora peak abundance was in spring with 3,333 individuals per m^2, and Eteone peak abundance was 1,667 individuals per m^2 in spring and autumn. Polydora and Eteone were also more abundant at the 2.14 meter station than any other stations at site MC. Peak abundance occurred in autumn with 113,334 organisms per m^2, and lowest abundance occurred in summer with 20,152 organisms per m^2 (Appendix C, Table 4, Figure 21).

Streblospio benedicti was the most common organism at the 1.22 station. Other abundant organisms included the cumacean Leucon sp., Macoma balthica, Corophium salmonis, Manayunkia aestuarina, and Polydora kempi japonica (Table 6). Streblospio population peaked in autumn with 9,849 individuals per m^2. Annelids peaked in autumn with 12,425 individuals per m^2 (Appendix C, Table 4; Fig. 22). Leucon sp. peak abundance occurred in autumn with 5,455 individuals per m^2. Total abundance was greatest in autumn (20,152 organisms per m^2) and lowest in spring (7,121 organisms per m^2) (Appendix C, Table 4; Fig. 21).

The most abundant macroinvertebrate at the MLLW station was Leucon sp.. Other abundant species included Streblospio benedicti, Manayunkia aestuarina, and Macoma balthica (Table 6). Oligochaete worms were also abundant. Leucon was most abundant in autumn with [illegible],061 individuals per m^2. Other organisms which had highest densities in autumn include: Streblospio (2,121 individuals per m^2) and Manayunkia (1,061 individuals per m^2). Oligochaetes were most

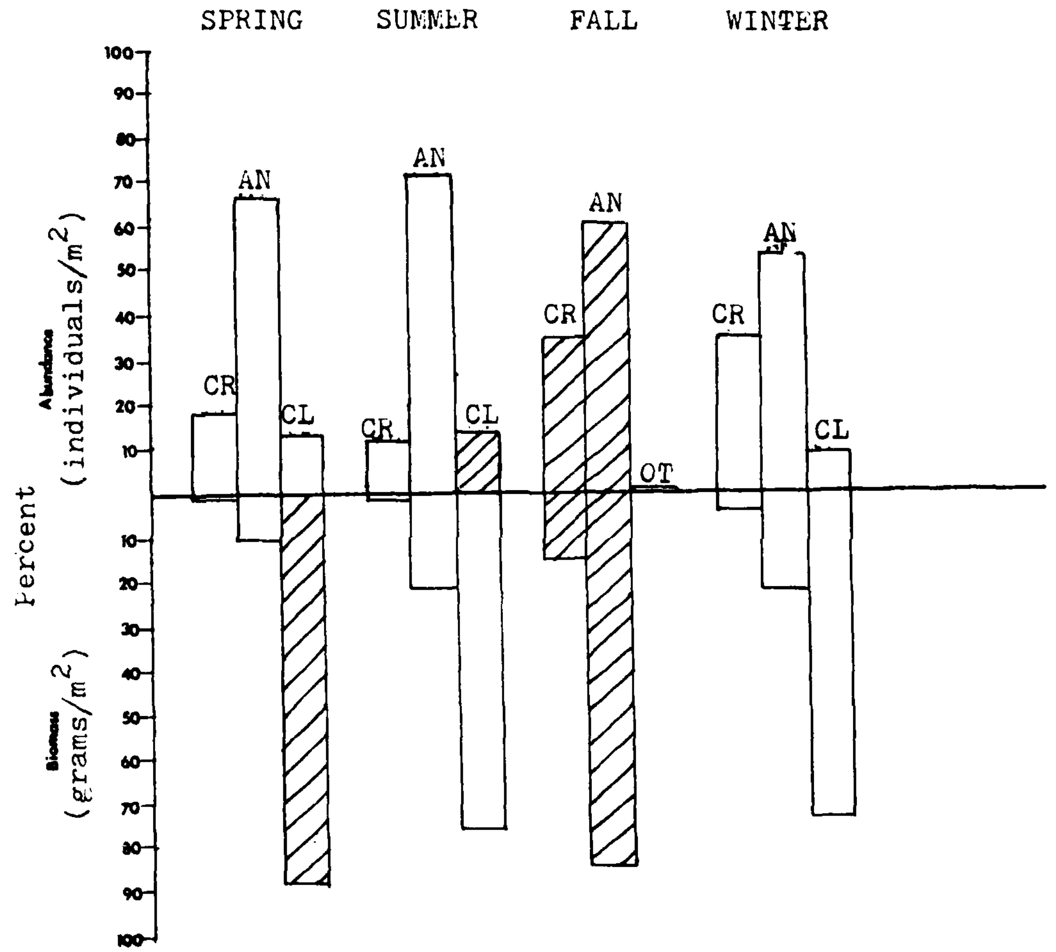

Figure 22. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 1.22 m station, Marsh Control site, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] See Figure 14 for footnote.

abundant in spring with 1,061 individuals per m^2. *Macoma balthica* was also most abundant in spring with 909 individuals per m^2 (Fig. 23).

Total abundance peaked at 11,364 organisms per m^2 in autumn and reached a low of 2,424 organisms per m^2 in winter (Appendix C, Table 4; Fig. 21).

Moon Island

The invertebrate community at 2.14 meter station was dominated by polychaete worms *Heteromastus filiformis* and *Streblospio benedicti*, and clams *Macoma bathica*, and *Mya arenaria* (Table 7), except in spring when community structure was dominated by *Pygosspio elegans*. This organism was not present in any other season or at any other station at this site. Overall station abundance was greatest in spring with 30,000 individuals per m^2 and lowest in summer with [illegible],304 individuals per m^2 (Appendix C, Table 5; Fig. 24). *Pygospio* population accounted for 74% of the overall abundance and 79% of the annelid abundance in spring (Fig. 25).

Organisms most abundant at 1.22 meters included *Corophium salmonis*, *Streblospio benedicti*, *Manayunkia aestuarina*, *Macoma balthica* and *Polydora ligni* (Table 7). Total abundance was greatest in winter (9,849 individuals per m^2) and lowest in summer (3,330 individuals per m^2), (Appendix G, Table 5; Fig. 24). *Corophium salmonis* was most abundant in winter with 4,849 individuals

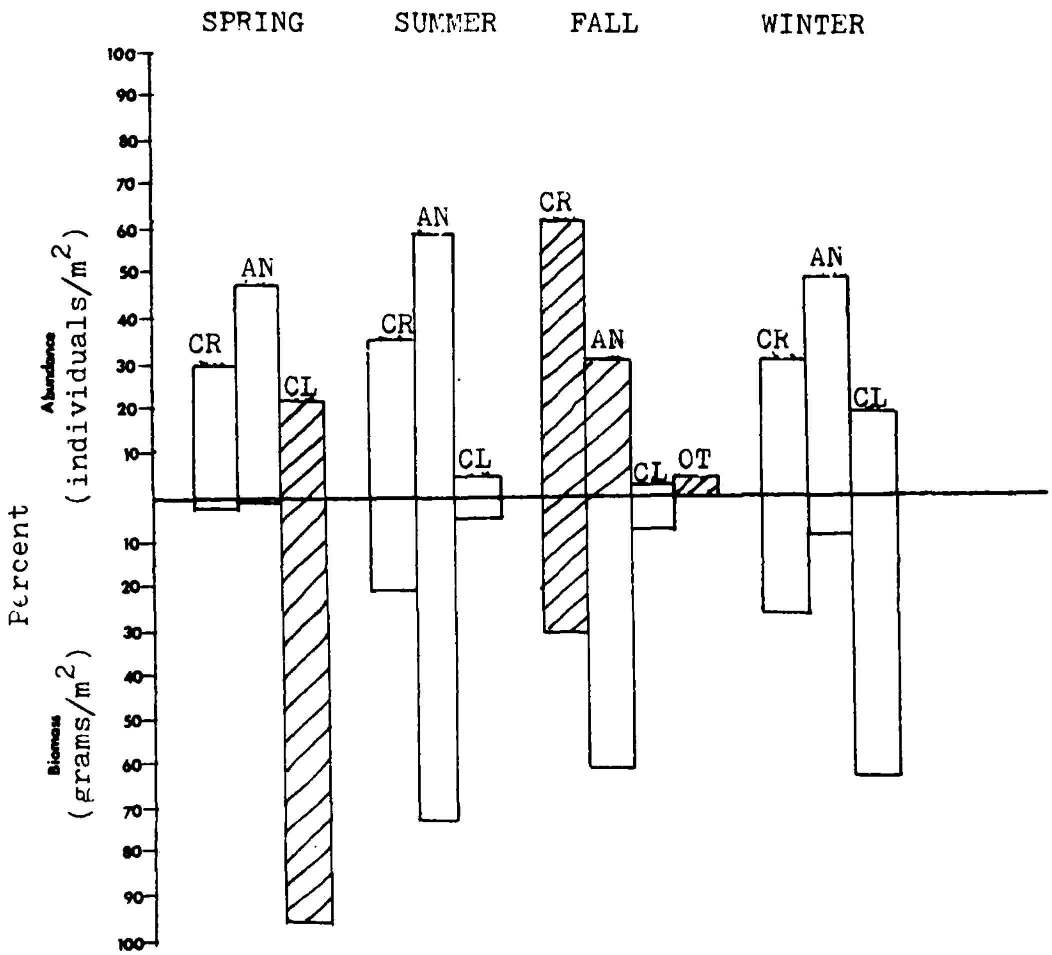

Figure 23. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the MLLW station, Marsh Control site, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

[1] See Figure 14 for footnote.

Table 7. Composition, by percent, of benthic invertebrate community, by season and station at Moon Island, Grays Harbor, Washington, 1980-81.

	Station											
	MLLW[1]				1.22				2.14			
Organism	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Corophium brevis	61	20	0	0	0	14	0	0	--	--	0	0
Corophium salmonis	0	8	5	8	0	27	16	49	--	--	0	0
Cumella 1, unid.	9	0	0	15	7	0	6	--	0	0	0	0
Eteone longa	0	--	0	0	0	0	--	0	--	17	0	0
Heteromastus filiformis	0	0	0	0	0	0	--	--	--	34	49	38
Macoma balthica	--	0	5	23	19	9	--	--	--	17	43	50
Manayunkia aestuarina	--	--	15	31	19	0	--	11	0	0	--	--
Mya arenaria	--	12	30	0	0	5	8	5	--	7	--	6
Oligochaeta	0	0	0	0	--	0	0	9	--	0	0	0
Polydora ligni	7	45	5	0	--	18	10	--	0	0	0	0
Pygospio elegans	0	0	0	0	0	0	0	0	74	0	0	0
Streblospio benedicti	--	--	25	8	22	14	36	12	12	7	0	0
All else	23	15	15	15	33	13	24	14	14	18	8	6
TOTAL STATION ABUNDANCE[2]	6,970	12,879	3,030	2,462	4,091	3,333	7,576	9,849	30,000	4,394	5,606	4,849

1 Elevation in meters relative to mean lower low water (MLLW); Bottom and side of navigation channel.

2 Mean numbers of individuals per m^2.

"--" = less than 5 percent; Blank = none present.

Table 7 Continued.

	Station							
	Bottom				Side			
Organism	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Corophium brevis	0	7	0	0	85	23	21	--
Corophium salmonis	0	0	0	0	0	15	13	7
Corophium spinicorne	9	0	0	--	7	12	--	0
Glycinde armigera	--	43	0	0	--	0	0	0
Glycinde picta	--	0	15	0	--	15	--	--
Leuron 1, unid.	0	0	0	9	0	0	--	9
Macoma balthica	6	7	20	9	--	0	0	6
Oligochaeta	40	7	5	45	0	--	--	--
Polydora ligni	0	7	0	0	3	--	35	0
Streblospio benedicti	30	7	30	21	--	0	--	57
All else	15	22	30	16	5	35	31	21
TOTAL STATION[2] ABUNDANCE	530	700	1,000	1,120	26,920	1,300	11,700	2,500

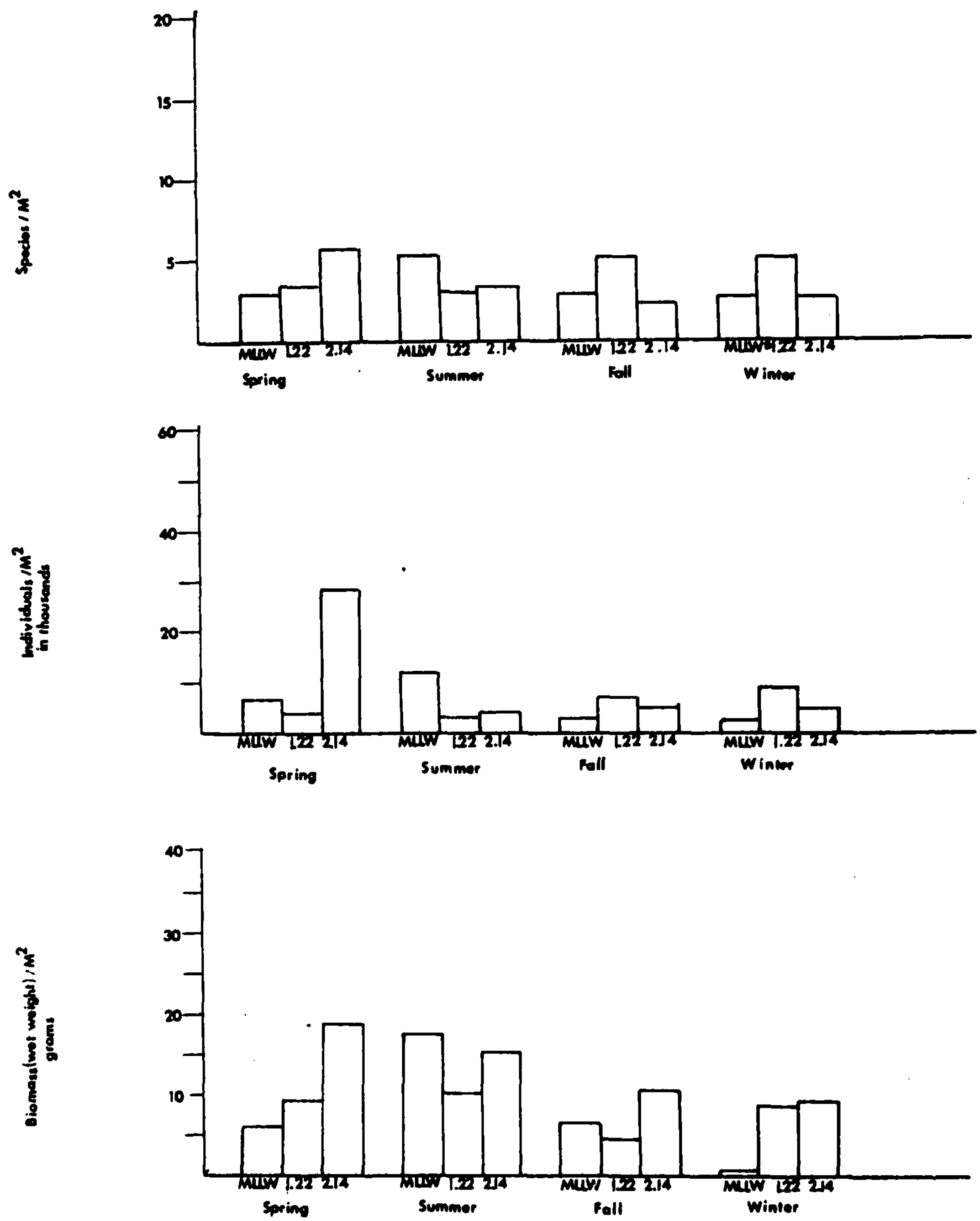

Figure 24. Mean number of species, individuals, and biomass per station (in meters relative to MLLW) seasonally at Moon Island, Grays Harbor, Washington, 1980-81.

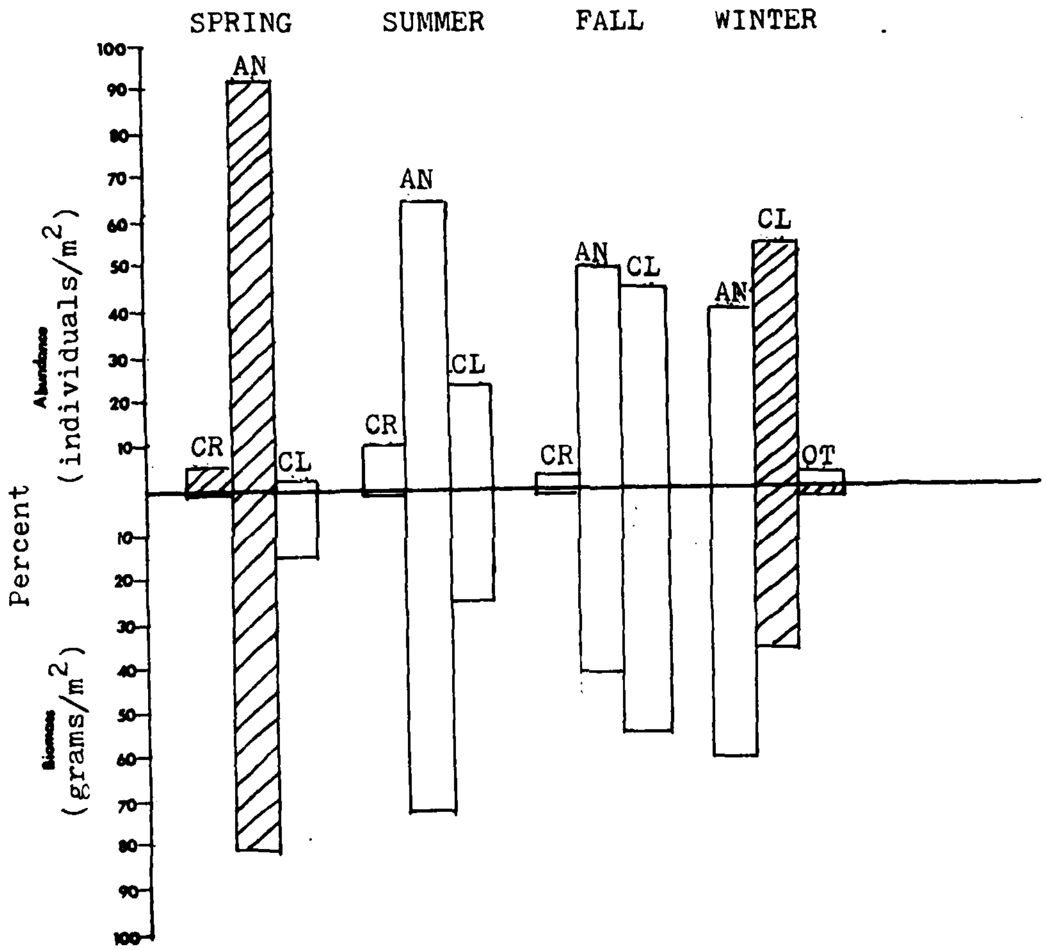

Figure 25. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 2.14 m station, Moon Island, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] See Figure 14 for footnote.

per m^2, which was 91% of crustacean abundance during winter (Fig. 26). Annelids reached peak abundance during autumn due mostly to high numbers of Streblospio, 2,727 individuals per m^2.

Corophium brevis, Polydora ligni, Manayunkia aestuarina, Mya arenaria, and Streblospio benedicti dominated the community at MLLW station (Table 7). Crustaceans were most abundant in spring with 5,303 individuals per m^2, of which 80% were Corophium brevis.

Total abundance was highest in summer with 12,879 organisms per m^2 and lowest in winter with 2,462 organisms per m^2 (Appendix C, Table 5; Fig. 24). Annelids were also at highest densities in summer (Fig. 27). Populations consisted mostly of Polydora ligni which comprised 45% of total abundance.

Dominant organisms at the channel side included 3 species of Corophium (C. brevis, C. salmonis, and C. spinicorne) and 2 polychaete worms (Polydora ligni and Streblospio benedicti (Table 7). Large numbers of Corophium brevis were present during spring (22,985 per m^2). Abundance of both crustaceans and invertebrates was highest during spring. C. brevis accounted for 90% of the crustaceans present during this sample period (Figs. 28 and 29).

Overall abundance was lowest in summer with 1,300 organisms per m^2 (Appendix G, Table 8). Peak abundances of other organisms included: Polydora, 4,100 individuals per m^2 in autumn; Corophium salmonis, 1,550 individuals per m^2 in autumn; Streblospio, 1,430

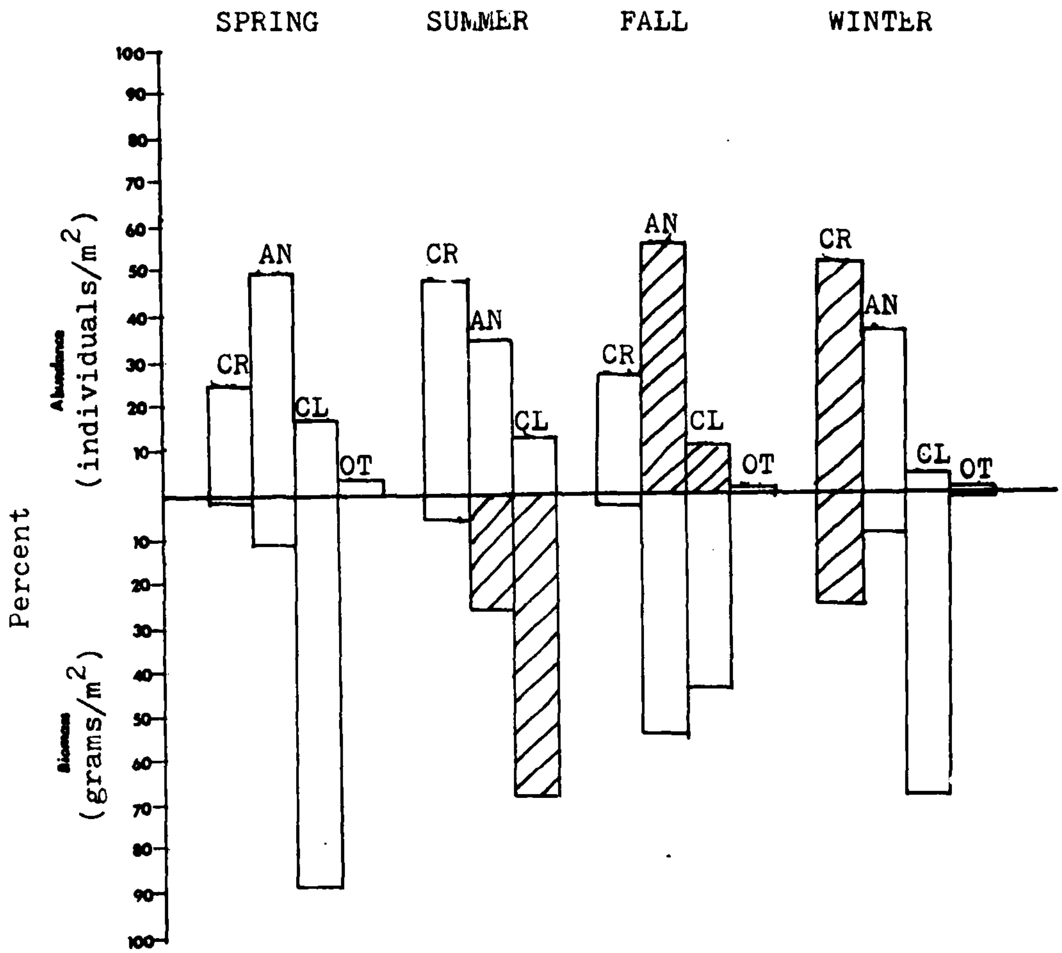

Figure 26. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the 1.22 m station, Moon Island, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] See Figure 14 for footnote.

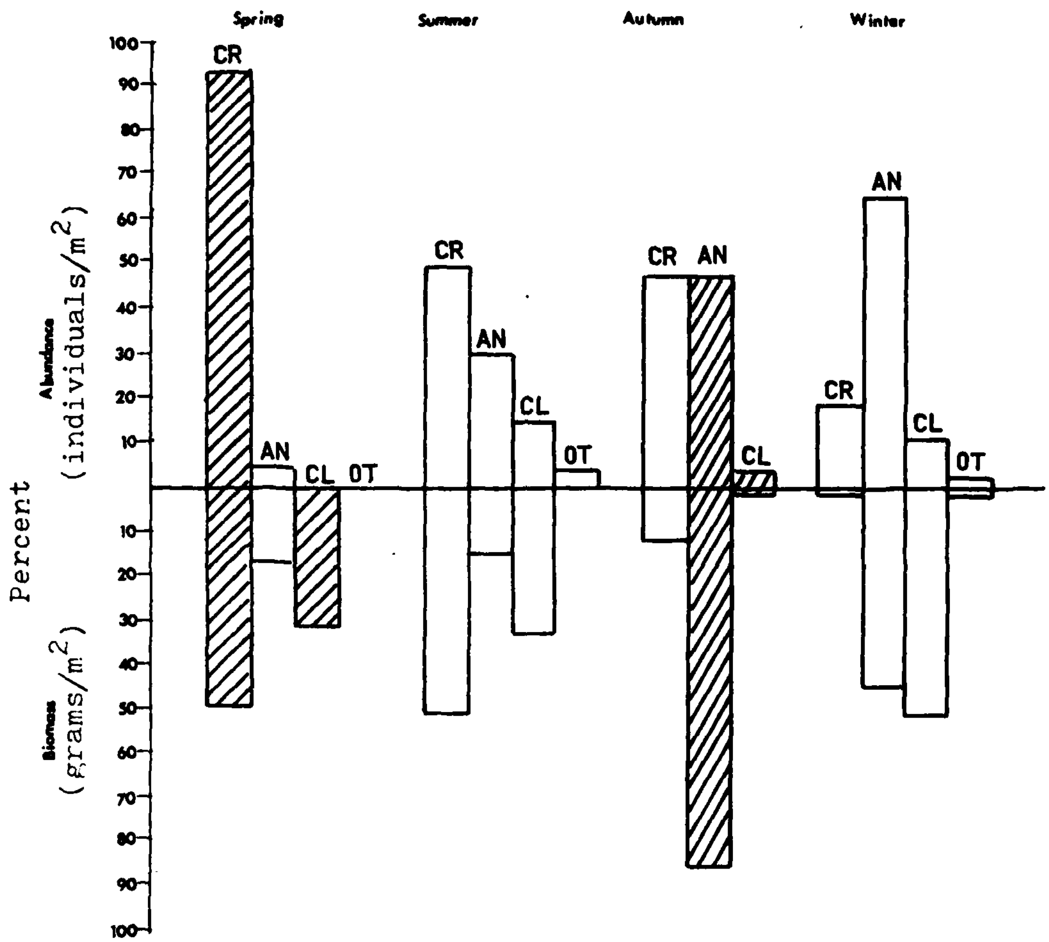

Figure 28. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the channel side station, Moon Island, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

[1] CR = crustaceans, AN = annelids, CL = clams, OT = other

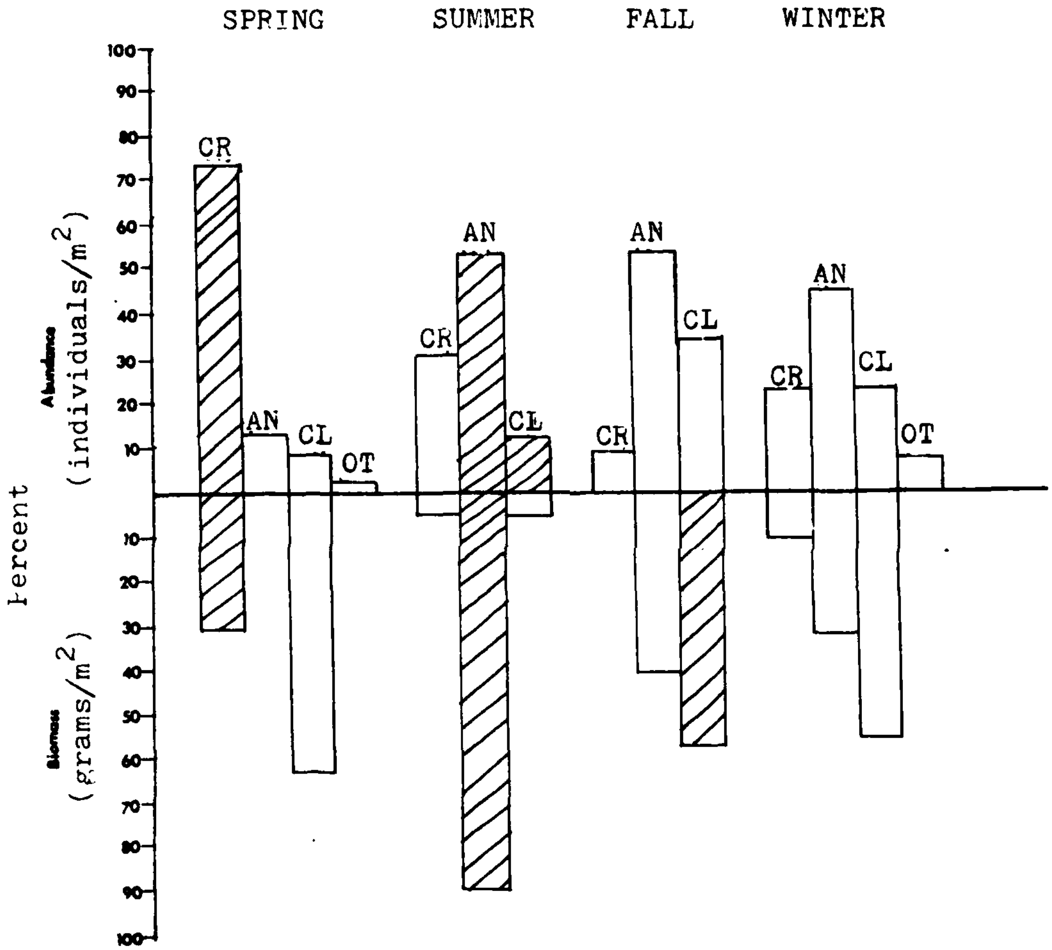

Figure 27. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the MLLW station, Moon Island, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

[1] See Figure 14 for footnote.

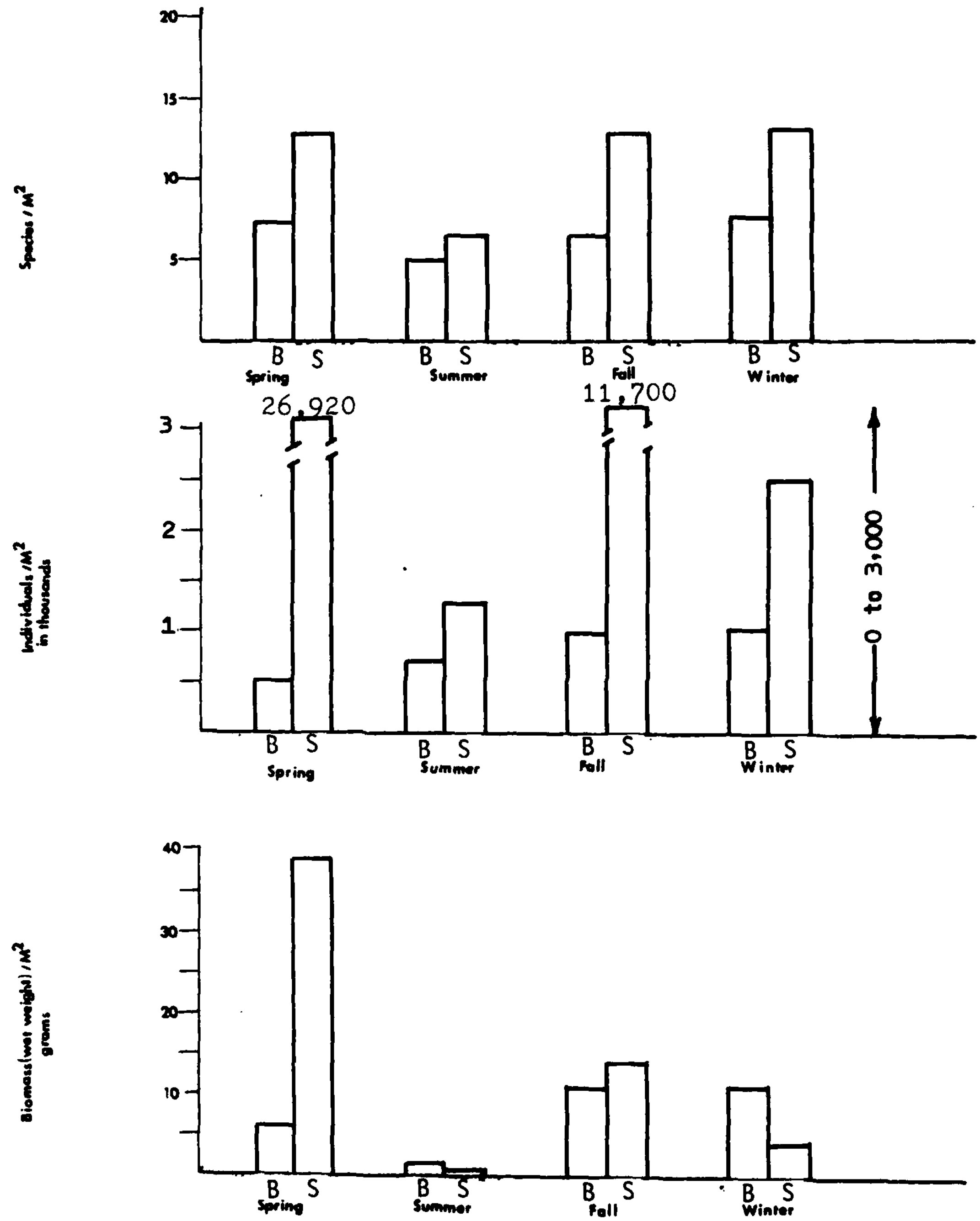

Figure 29. Mean number of species, individuals, and biomass at the bottom (B) and the side (S) of the navigation channel stations seasonally, at Moon Island, Grays Harbor, Washington, 1980-81.

individuals per m^2 in winter and; _Corophium spinicorne_, 1,850 individuals per m^2 in spring.

Oligochaetes, _Streblospio benedicti_, _Macoma balthica_ and _Glycinde armigera_ were the dominant invertebrates on the channel bottom (Table 8). Highest total abundance (1,120 organisms per m^2) and annelid abundance (785 individuals per m^2) occurred in winter (Fig. 30). Abundance was lowest, 530 organisms per m^2, in spring (Appendix C, Table 8; Fig. 29). Peak abundances of dominant organisms were: oligochaetes, 500 individuals per m^2 in winter; _Streblospio_, 300 individuals per m^2 in autumn; _Macoma balthica_, 200 individuals per m^2 in autumn, and, _Glycinde armigera_, 300 individuals per m^2 in summer.

Top of the Crossover Channel

Macoma spp., was the most common invertebrate at the Channel Side Station, followed by _Nephtys longosetosa_, oligochaetes and _Scolelepis squamata_ (Table 8). Clams reached peak density in spring with 285 individuals per m^2 (Fig. 31, Appendix C, Table 9). However, the lowest total density also occurred in spring, with 340 organisms per m^2. Total density peaked at 950 organisms per m^2 in autumn. Annelid populations also peaked in autumn at 650 individuals per m^2.

Organisms representative of the channel bottom include _Glycinde picta_, _Corophium spinicorne_, _Armandia brevis_, _Macoma_ spp.,

Table 8. Composition, by percent, of benthic invertebrate community, by season and station at the Top of the Crossover Channel, Grays Harbor, Washington, 1980-81.

Organism	Bottom[1] Spring	Bottom[1] Summer	Bottom[1] Autumn	Bottom[1] Winter	Side Spring	Side Summer	Side Autumn	Side Winter
CRUSTACEA								
Archaeomysis grebnitskii	0	0	5	--	0	0	0	6
Balanus sp.	0	0	5	0	0	0	0	0
Corophium 1, unid.	0	0	14	0	0	0	0	0
Corophium spinicorne	--	36	0	0	0	0	0	0
Eogammarus, all sp.	0	18	--	5	0	0	0	14
Lamprops, *Hemilamprops*, or *Mesolamprops* sp.	0	0	10	11	0	0	5	8
Paraphpxus milleri	0	0	0	0	0	0	0	23
ANNELIDA								
Armandia brevis	22	0	8	12	0	20	0	0
Chaetozone spinosa	0	0	0	0	0	0	11	0
Glycinde picta	38	0	--	12	--	0	5	6
Nephtys longosetosa	0	0	0	--	0	20	5	--
Nephtys sp.	0	18	0	0	0	10	0	0
Oligochaeta	0	0	0	--	0	0	21	--
Paraonidae	0	0	0	0	0	0	0	6
Polydora ligni	0	0	27	0	--	0	0	0
Scolelepis squamata	--	9	0	0	--	20	0	0
Streblospio benedicti	0	0	0	--	0	0	11	0
MOLLUSCA								
Macoma, all sp.	26	0	0	6	84	30	5	8
OTHER								
Nemertea	--	0	--	16	--	0	0	--
All else	14	19	31	38	16	0	37	29
TOTAL STATION[2] ABUNDANCE	690	550	2,960	1,310	340	500	950	490

1 Bottom and side of navigation channel.
2 Mean numbers of individuals per m^2.
"--" = less than 5 percent
Blank = none present

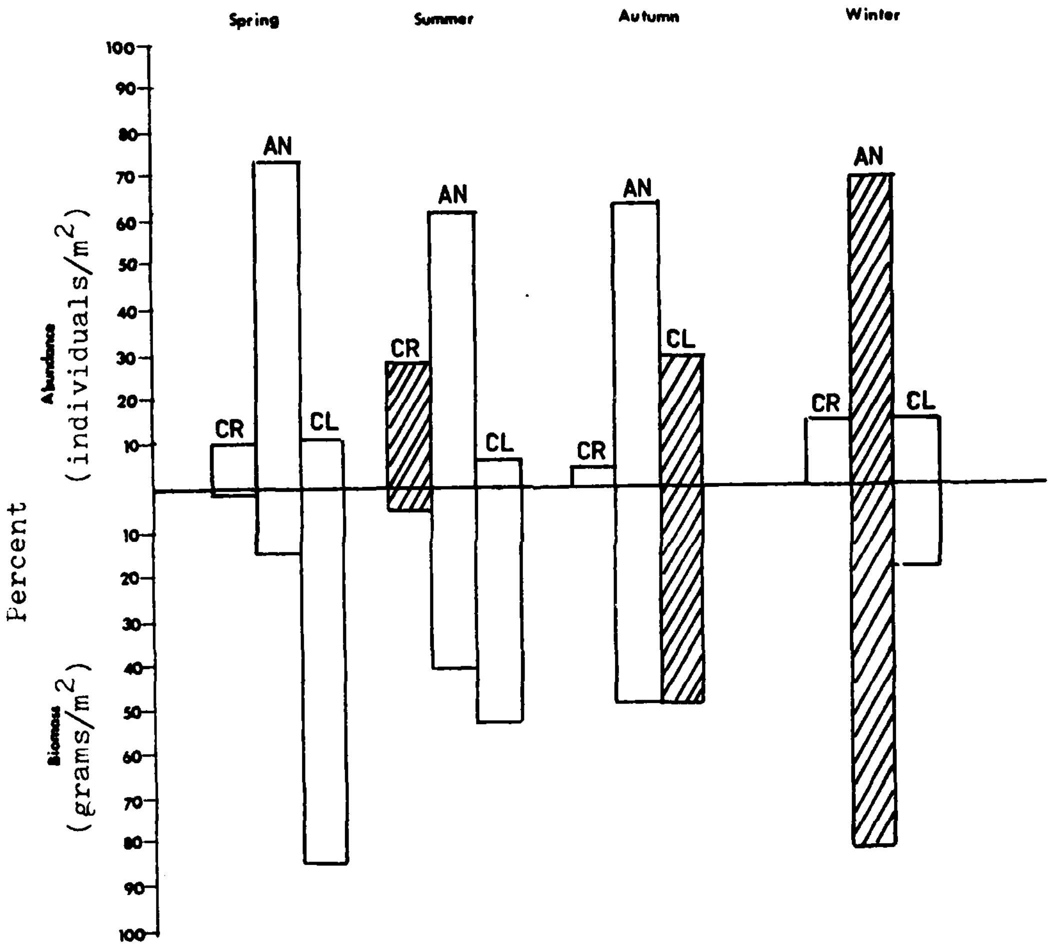

Figure 30. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the channel bottom station at Moon Island, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other

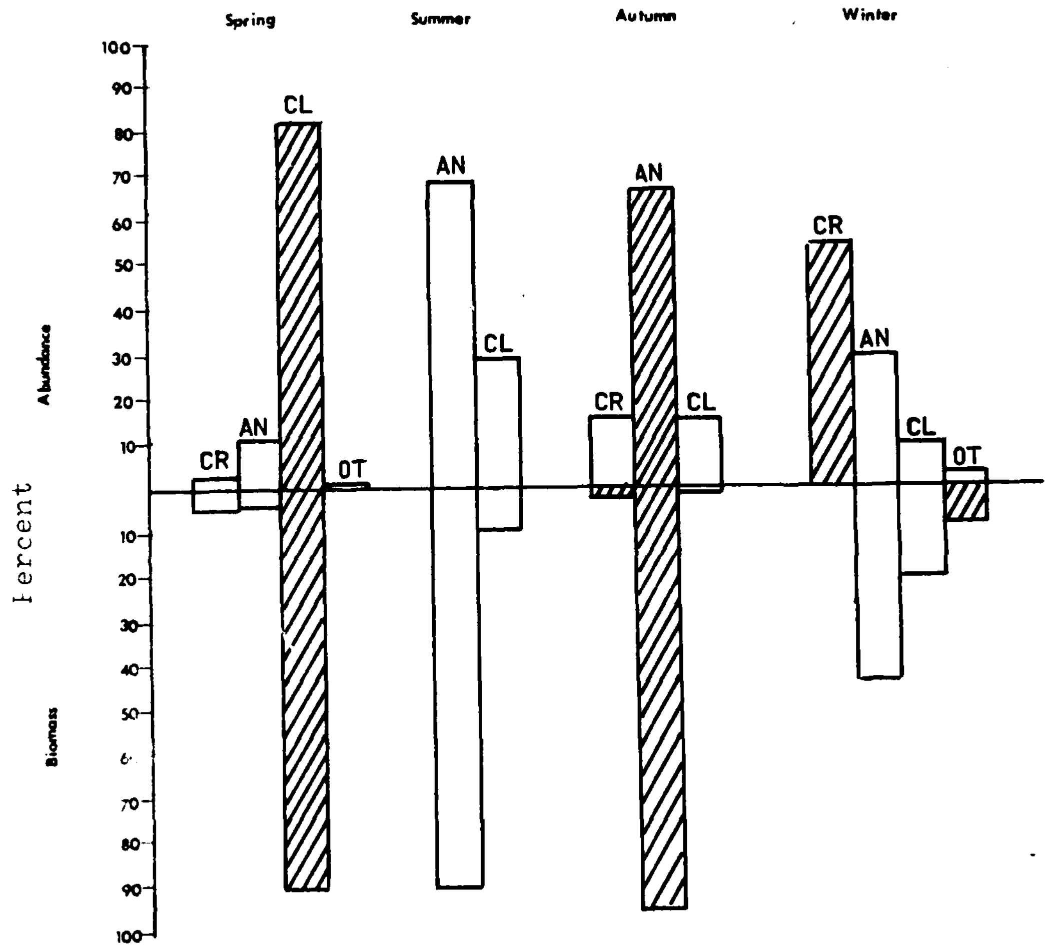

Figure 31. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the channel side station, Top of the Crossover Channel, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

[1] CR = crustaceans, AN = annelids, CL = clams, OT = other

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GRAYS HARBOR AND CHEHALIS RIVER IMPROVEMENTS TO NAVIGATION ENVI--ETC(U)
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and *Polydora ligni* (Table 8). Annelid (1,350 individuals per m^2) and crustacean (1,410 individuals per m^2) populations peaked in autumn with clam populations (180 individuals per m^2) peaking in spring (Fig. 33). Overall density was highest in autumn (2,960 organisms per m^2) and lowest in summer with 550 organisms per m^2 Appendix C, Table 9: Figure 32).

Whitcomb Flats

The most common species at the channel side station were *Magelona sacculata*, *Paraphoxus milleri*, *Spio* sp., *Eohaustorius* sp., *Ophelia limacina* and *Archaeomysis grebnitzkii* (Table 9).

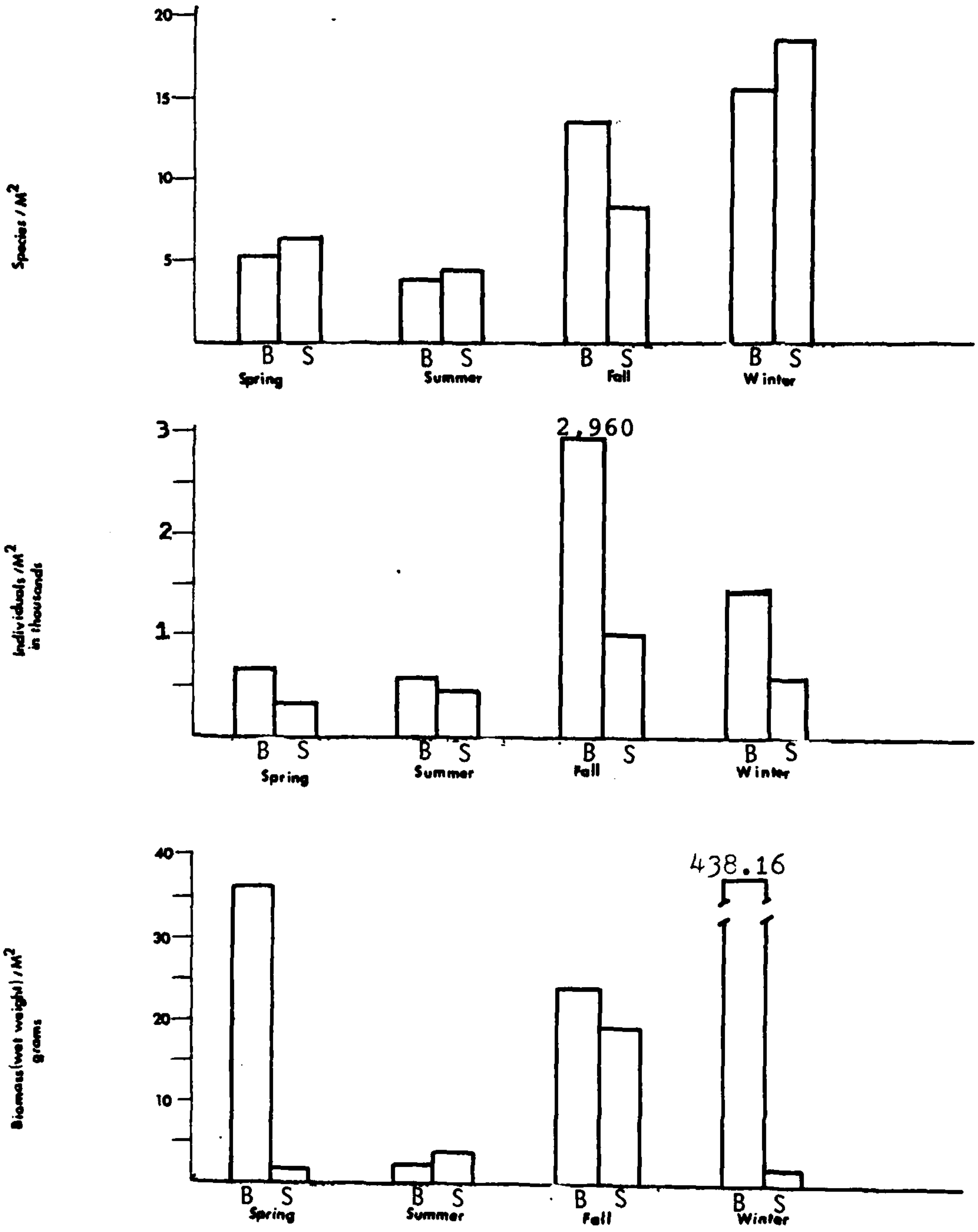

Figure 32. Mean number of species, individuals, and biomass at the bottom (B) and side (S) stations of the navigation channel, seasonally, at the Top of the Crossover Channel, Grays Harbor, Washington, 1980-81.

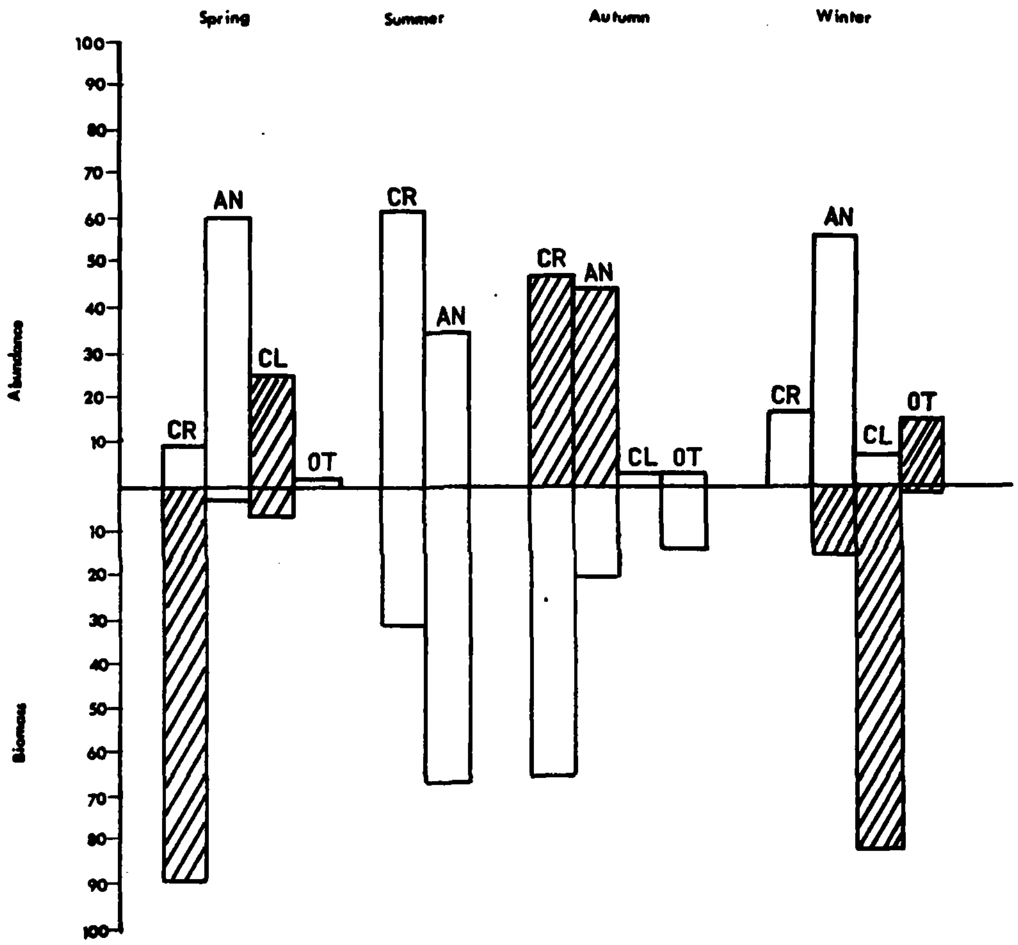

Figure 33. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the channel bottom station, Top of the Crossover Channel, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other.

Crustacean abundance was highest in summer (Fig. 34). Populations were composed entirely of _Paraphoxus_ (190 individuals per m^2) and _Eohaustorius_ (115 individuals per m^2). Total density at this station was lowest in autumn with 405 organisms per m^2 (Appendix G, Table 10; Fig. 35).

The invertebrate community on the channel bottom was composed mainly of _Spio_ sp. _Magelona sacculata_, _Ophelia limacina_, _Mediomastus_ sp., _Archaeomysis grebnitzkii_ and _Paraphoxus milleri_ (Table 9).

Annelid populations peaked at 1,750 individuals per m^2 and total density at this station peaked at 2,070 organisms per m^2 in summer (Fig. 36). Both _Siliqua patula_ and _Dendraster excentricus_ were present at this station in low numbers, 5 individuals per m^2.

Deepwater Disposal

The benthic community at this site was primarily composed of _Magelona sacculata_, nemerteans, _Ophelia limacina_ and _Archaeomysis grebnitzkii_ (Table 10).

In autumn, populations of annelids (770 per m^2), and crustaceans (160 per m^2), peaked, as did the total number of invertebrates (1,010 per m^2)(Fig. 37; Appendix C, Table 11). _Magelona_ populations were highest in spring with 485 individuals per m^2. Nemerteans were most abundant in summer (300 individuals per m^2).

Other organisms found at this site include: _Siliqua patula_, 25 individuals per m^2 in autumn; and _Dendraster excentricus_, 50

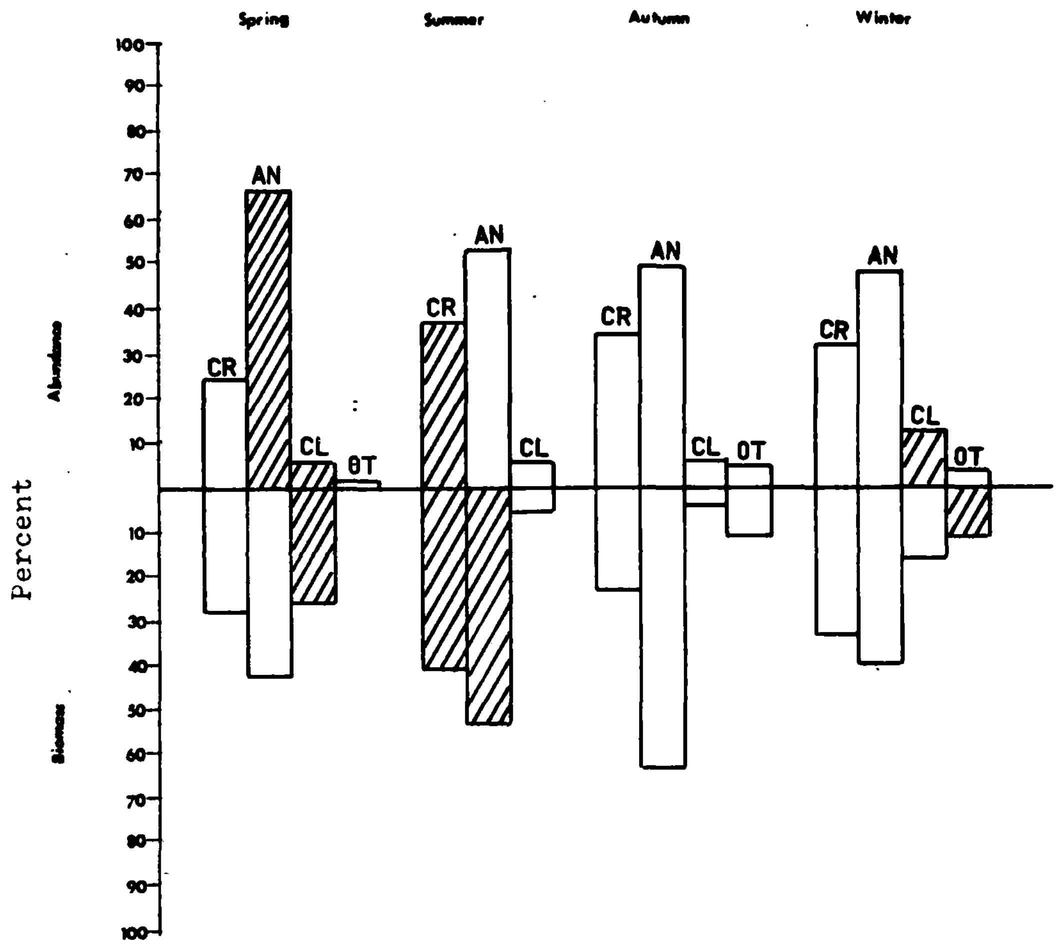

Figure 34. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the channel side station, Whitcomb Flats, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other

Table 9. Composition, by percent, of benthic invertebrate community by station and season at Whitcomb Flats, Grays Harbor, Washington, 1980-81.

	Bottom[1]				Side			
Organism	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
CRUSTACEA								
Archaeomysis grebnitskii	--	--	15	5	--	0	--	20
Eohaustorius sp.	0	0	0	0	6	14	5	10
Mandibulophoxus gilesi	10	0	--	0	0	0	0	--
Paraphoxus milleri	--	--	15	5	18	24	20	0
ANNELIDA								
Hesionidae	0	10	0	0	0	0	0	0
Magelona sacculata	38	--	0	19	53	16	7	18
Mediomastus sp.	0	65	0	--	5	--	--	0
Nephtys longosetosa	--	0	6	--	--	0	--	--
Ophelia limacina	--	--	41	6	--	8	15	7
Scoloplos armiger	0	0	0	15	0	12	--	--
Spio, all sp.	31	--	--	35	5	--	20	18
MOLLUSCA								
Cryptomya californica	--	7	--	0	--	--	0	--
Siliqua (patula)	0	--	0	--	--	0	--	9
Tellina nuculoides	--	0	6	0	--	6	0	--
OTHER								
Dendraster excentricus	0	0	0	--	0	0	5	--
Nematoda	0	0	6	0	0	0	0	0
All else	21	18	11	15	13	20	28	18
TOTAL STATION[2] ABUNDANCE	1,365	2,070	1,700	310	1,050	805	405	460

1 Bottom and side of navigation channel.

2 Mean numbers of individuals per m^2.

"--" = less than 5 percent

"0" = not present

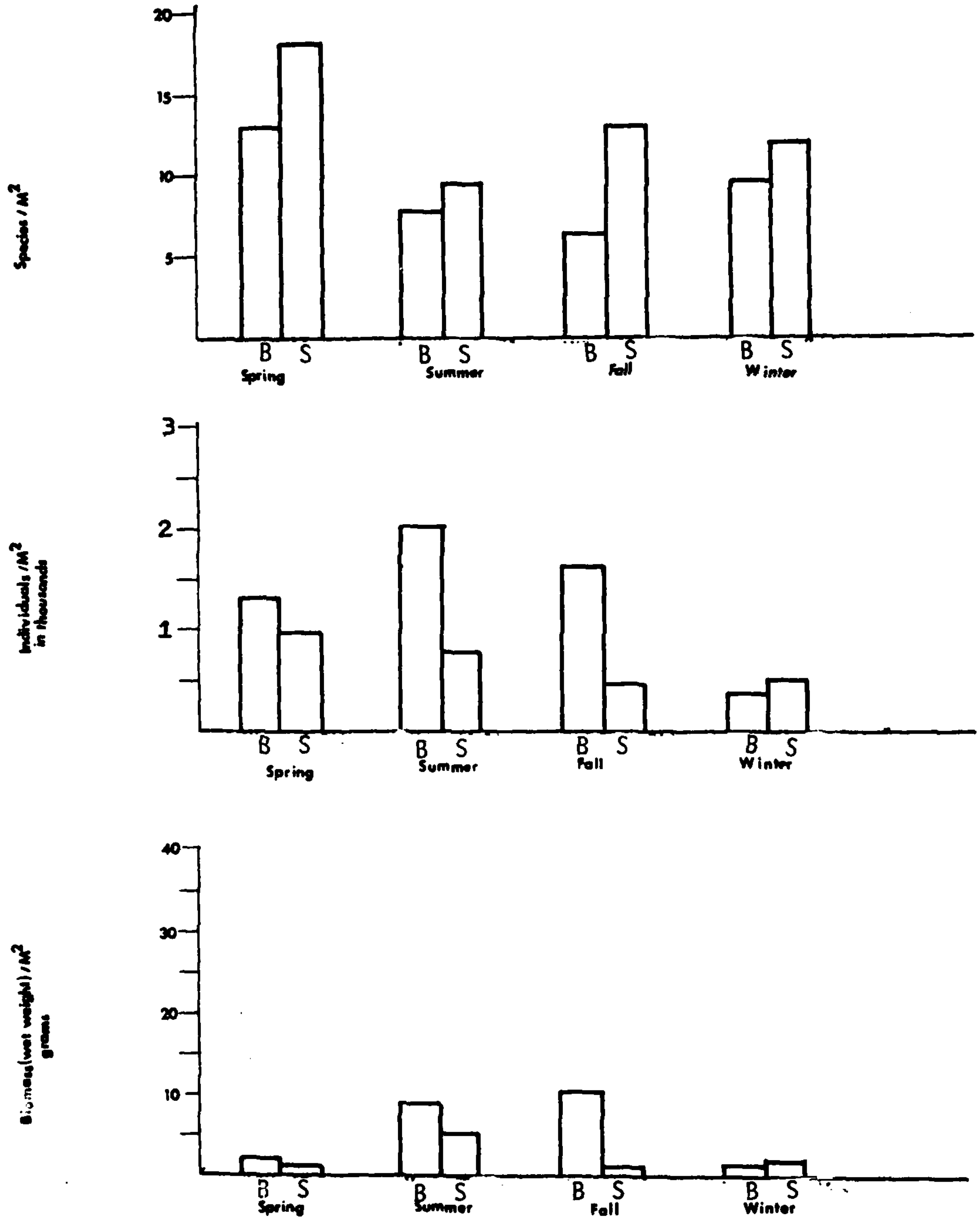

Figure 35. Mean number of species, individuals, and biomass at the bottom (B) and side (S) station, seasonally, at Whitcomb Flats, Grays Harbor, Washington, 1980-81.

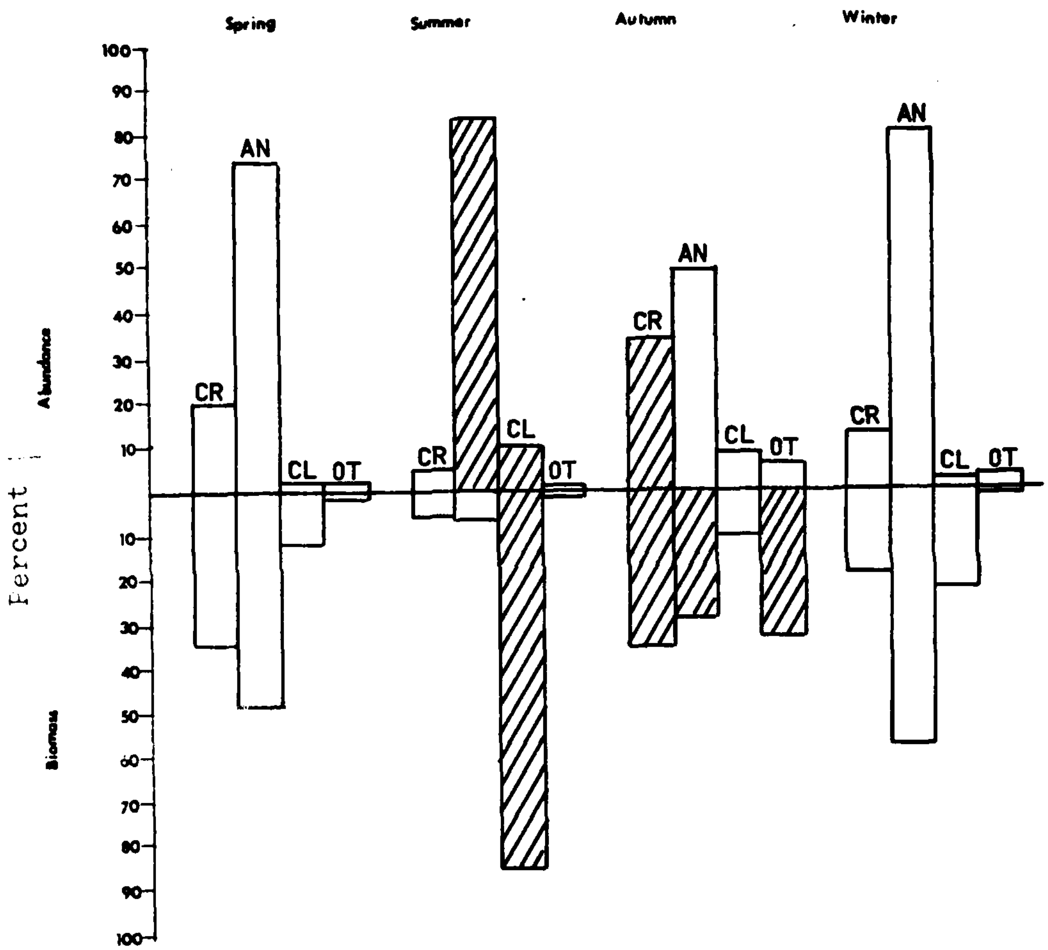

Figure 36 Percent of invertebrate community occupied by four major categories[1] of invertebrates at the channel bottom station, Whitcomb Flats, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

[1] CR = crustaceans, AN = annelids, CL = clams, OT = other.

Table 10. Composition, by percent, of benthic invertebrate community, by season present at the Deepwater Disposal Area, Grays Harbor, Washington, 1980-81.

Organism	Bottom[1] Spring	Summer	Autumn	Winter
CRUSTACEA				
Archaeomysis grebnitzkii	--	0	10	6
Paraphoxus milleri	0	0	--	9
ANNELIDA				
Glycera capitata	0	13	--	--
Hemipodus borealis	0	0	0	9
Hesionidae 1, unid.	0	0	--	9
Magelona sacculata	66	0	28	4
Ophelia limacina	6	6	35	--
Scoloplos armiger	4	0	--	--
MOLLUSCA				
Tellina nuculoides	--	0	--	4
OTHER				
Dendraster excentricus	--	0	--	15
Nemertea	--	38	--	19
All else	24	43	27	25
TOTAL STATION[2] ABUNDANCE	730	800	1,010	340

1 Bottom depth only existed here.

2 Mean number of individuals per m^2.

"--" = less than 5 percent

"0" = not present

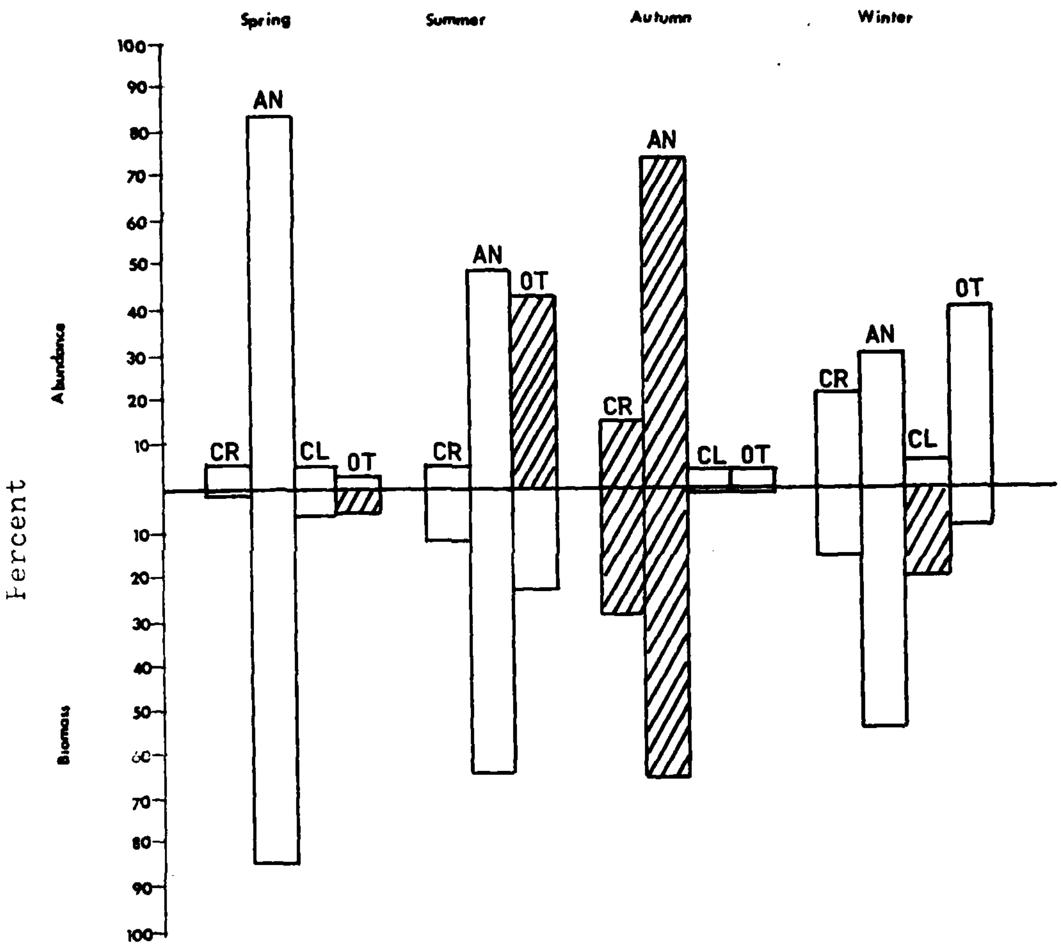

Figure 37. Percent of invertebrate community occupied by four major categories[1] of invertebrates, Deepwater Disposal Site, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other.

individuals per m^2 in winter. Lowest abundance occurred in winter (340 organisms per m^2)(Fig. 38).

South Jetty

The dominant organism at the South Jetty was the barnacle (Balanus sp.), which formed a dense cover over cobbles, larger gravel and old clam shells. Sand accumulated between barnacles and in the spaces inside dead barnacles. These, along with shells, provided a new habitat at this site.

Other important organisms at this site include: amphipods Paraphoxus spinosus, Parapleustes pugettensis, members of the family Ischyroceridae, and the polychaetes Syllidae sp., Eulalia sp. and Phyllodoce maculata (Table 11).

Abundances of all faunal groups peaked in spring and were lowest in winter (Appendix C, Table 12; Fig. 39, 40 and 41). Peak numbers of most species occurred during spring, with maximum densities as follows: Balanus sp. 26,980; Paraphoxus spinosus 1,050; Syllidae sp. 700; Parapleustes sp. 700; Ischyroceridae sp. 1,650; Eulalia sp. 1-700 and Phyllodoce maculata 1,400 individuals per m^2.

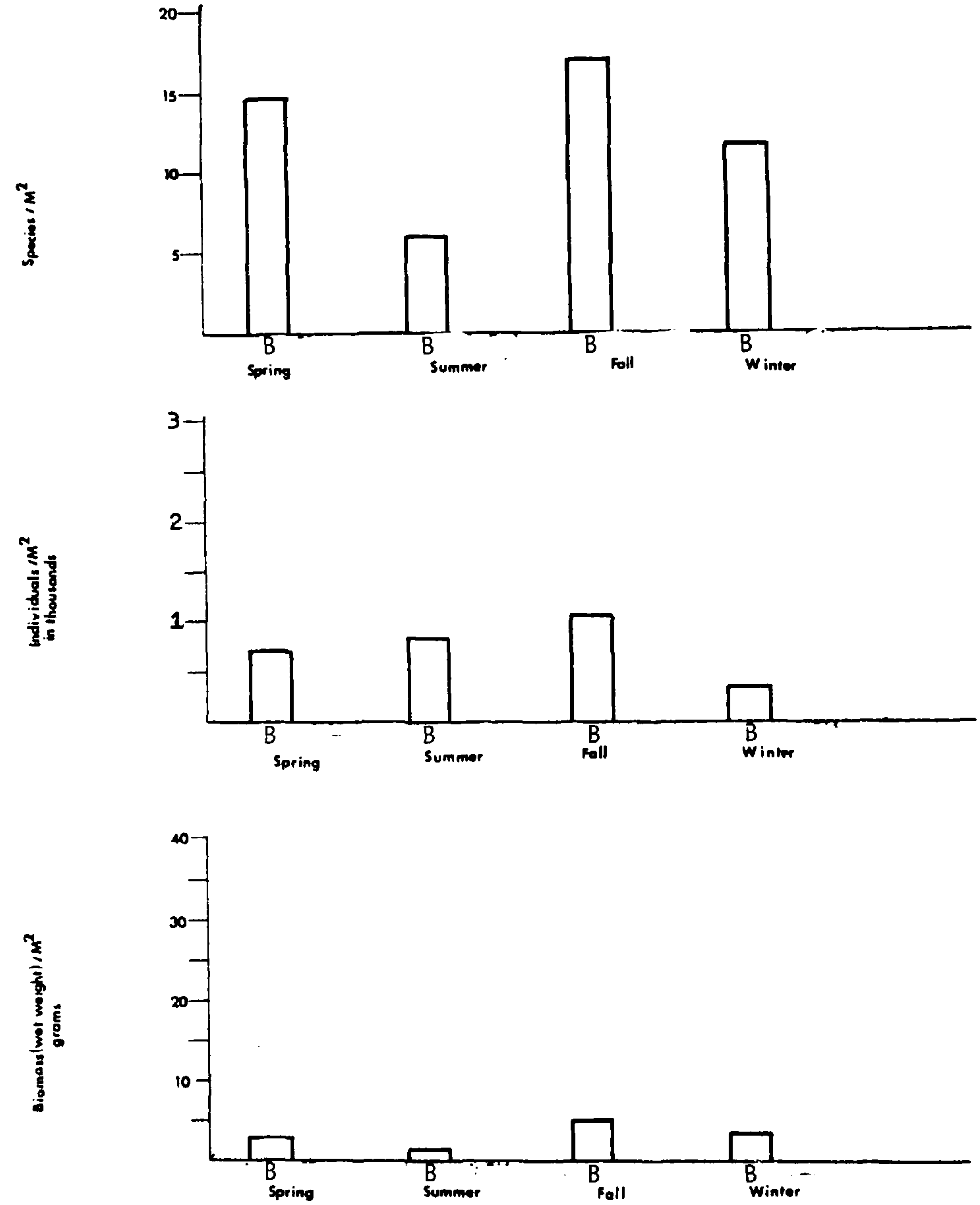

Figure 38. Mean number of species, individuals, and biomass, seasonally, at the Deepwater Disposal site, Grays Harbor, Washington, 1980-81.

Table 11. Composition, by percent, of benthic invertebrate community by season at the South Jetty, Grays Harbor, Washington, 1980-81.

	Bottom[1]				Bottom (excluding barnacles)			
Organism	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
CRUSTACEA								
Balanus sp.	68	86	87	84	0	0	0	0
Caprella, all sp.	3	0	--	0	10	0	--	0
Diastylopsis 1, unid.	0	0	1	0	0	0	7	0
Ischyroceridae, all sp.	4	2	1	0	13	12	5	0
Paraphoxus spinosus	3	4	3	3	9	27	22	17
Parapleustes (*pugettensis*?)	2	2	1	0	6	15	11	0
ANNELIDA								
Armandia brevis	--	--	2	1	--	--	14	9
Capitella sp.	0	0	--	2	0	0	--	13
Eulalia 1, unid.	2	1	--	1	6	10	--	9
Lumbrineridae, all sp.	1	--	0	0	4	--	0	0
Pleanotus bellis	1	0	1	0	3	0	5	0
Phyllodoce maculata	4	0	--	2	11	0	--	13
Syllidae, all sp.	2	2	--	3	6	12	--	22
OTHER								
Pycnogonida, all sp.	1	0	0	0	3	0	0	0
Nemertea	3	--	--	--	9	--	--	--
All else	6	3	4	4	20	24	36	17
TOTAL STATION[2] ABUNDANCE	39,430	14,825	10,715	1,460	12,300	2,070	1,415	230

1 Bottom depth only existed here.

2 Mean numbers of individuals per m^2.

"--" = less than 5 percent

"0" = none present

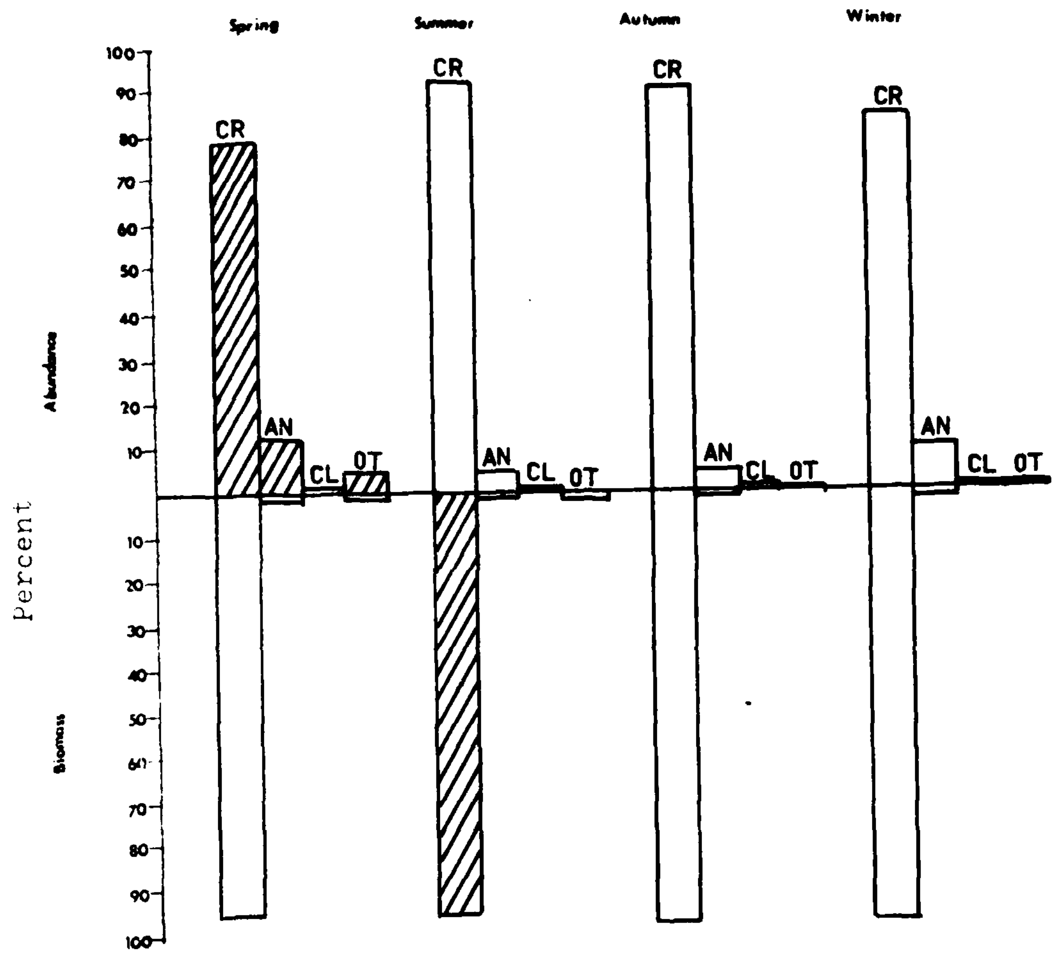

Figure 39. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the South Jetty, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other.

* Data from one van Veen grab sample only.

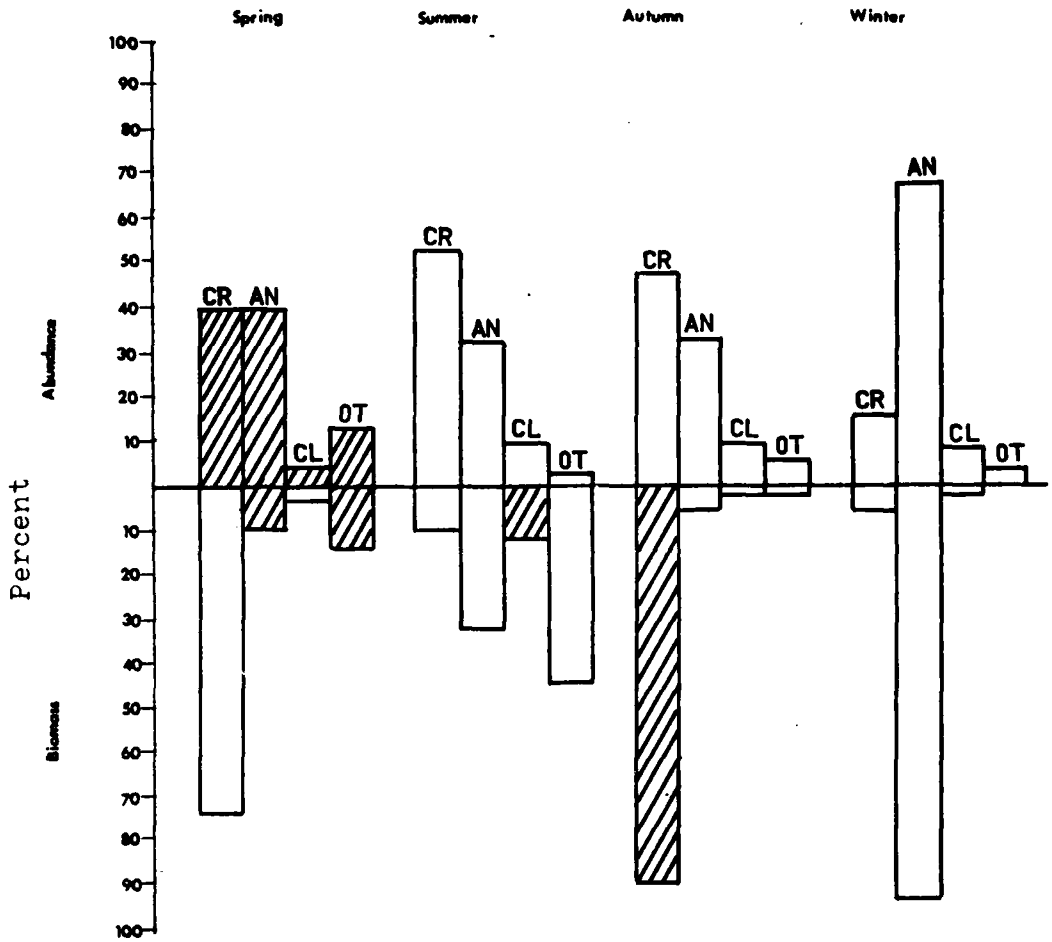

Figure 40. Percent of invertebrate community occupied by four major categories[1] of invertebrates at the South Jetty, Grays Harbor, Washington, 1980-81. Patterned bars indicate peak abundance or biomass within that category for the year.

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[1] CR = crustaceans, AN = annelids, CL = clams, OT = other.

* Data from one van Veen grab sample only.

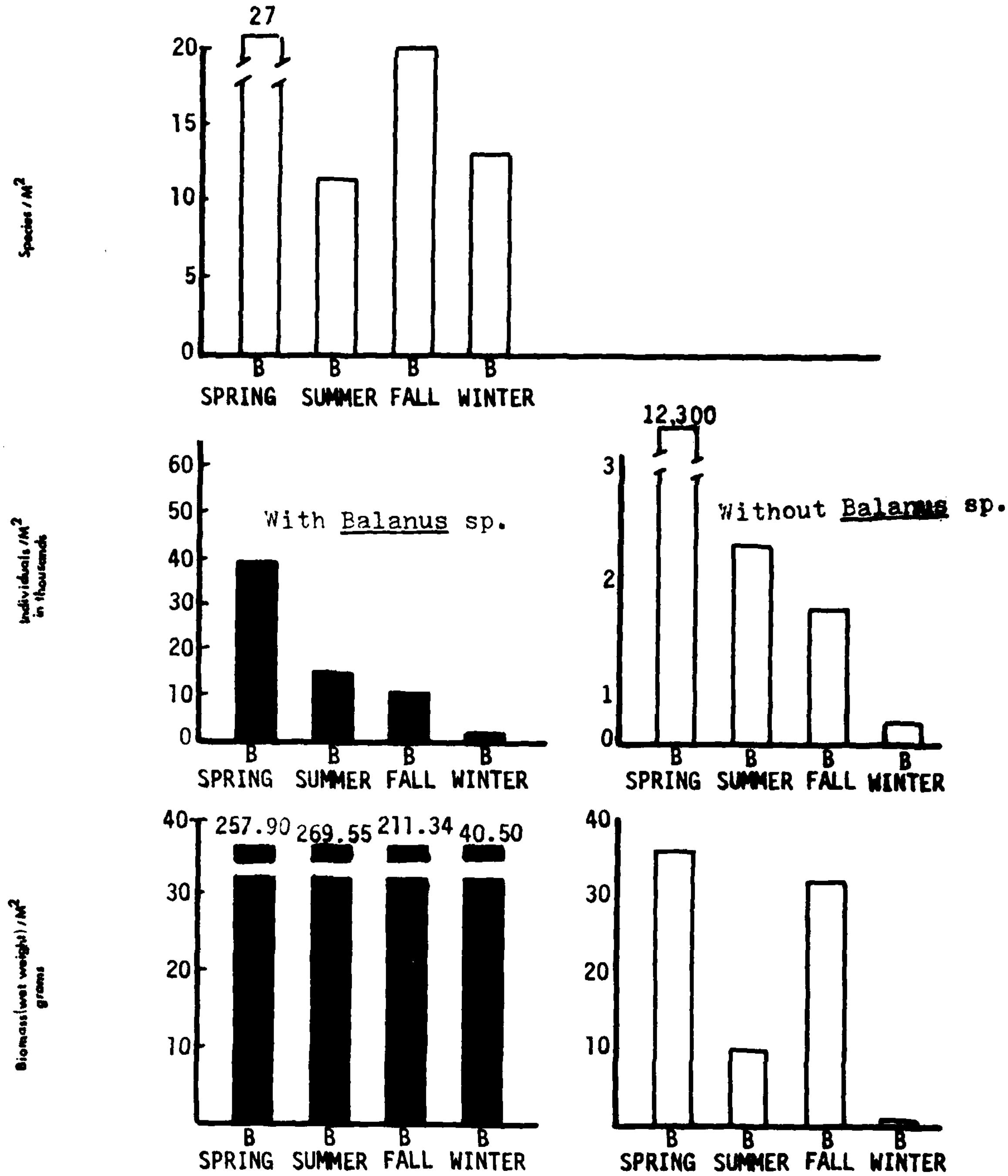


Figure 41. Mean number of, species, individuals (with and without *Balanus* sp.), and biomass (with and without *Balanus* sp.) at the South Jetty, Grays Harbor, Washington, 1980-81.

Diversity

Intertidal

In general, for all intertidal sites, diversity values were lowest at the 2.14 m station (Fig. 42). Diversity was inversely related to elevation above MLLW. This did not hold for the Moon Island site where diversity was highest at the 1.22 m station. The diversity at the MLLW station on the Moon Island site may have been lower because of the dynamic nature of the substrate at this station. Siltation and erosion occurred throughout the year. This activity seemed to be related to dredging activity adjacent to or upstream from the site.

Diversity increased sharply at the 2.14 m stations on site MC and MI during summer and fell sharply during fall (Appendix E, Table 1). Diversity was most similar at the same stations between sites in autumn and most dissimilar in summer (Fig. 42). This occurred because of a reduction in both species and numbers of individuals/species in winter. This may have been related to site location, as those sites located most seaward showed highest reductions.

Subtidal

In general, a gradient existed from lower diversity values in the inner harbor to higher diversity values in the outer harbor (Fig. 43).

Values ranged from a low of .100 at Cosmopolis, side of the channel station in winter, to 3.002 at South Jetty in spring (Appendix E, Table 2). At Cow Point, the channel bottom had

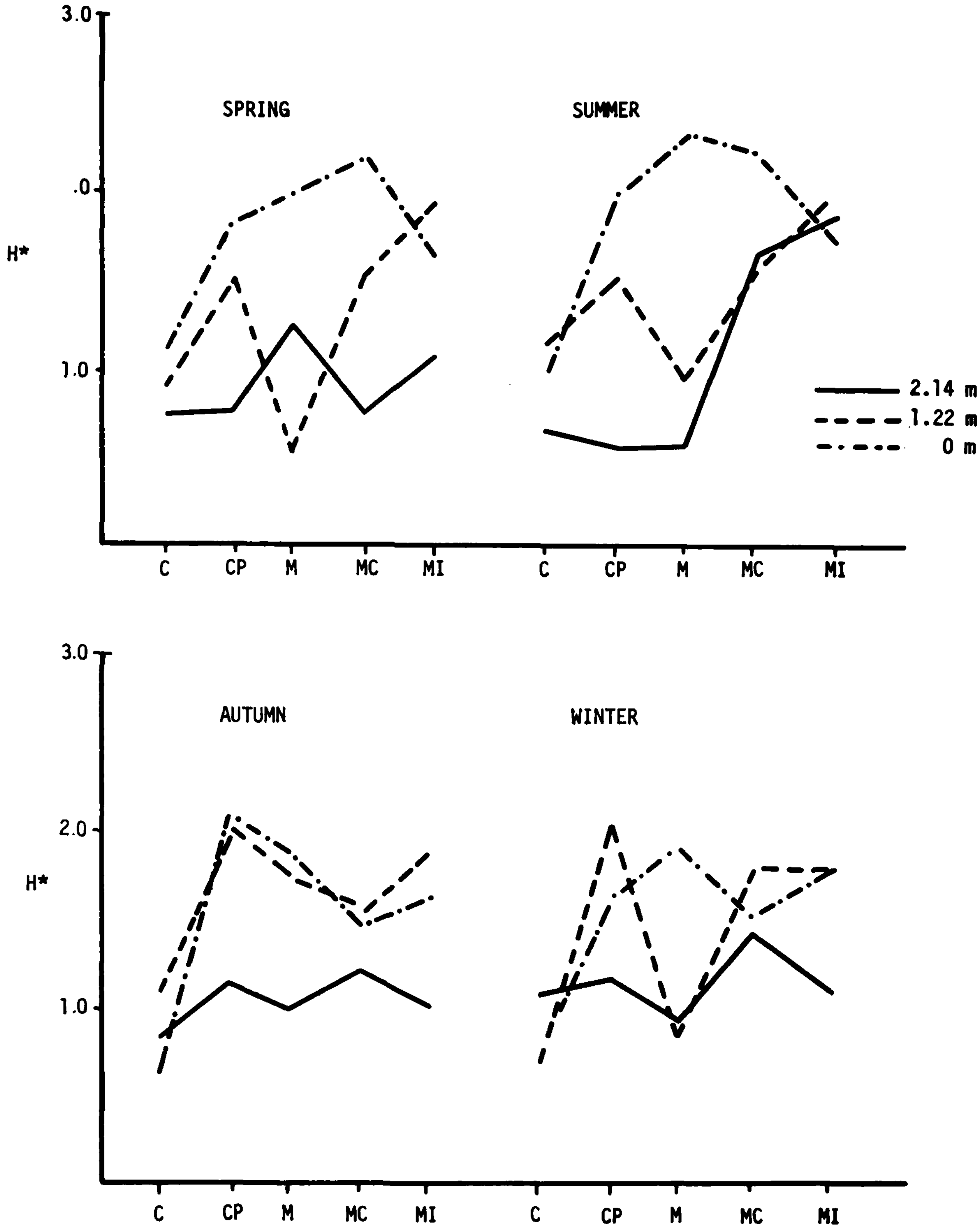


Figure 42. Diversity (H*) values for intertidal stations by season, Grays Harbor, Washington, 1980-81.

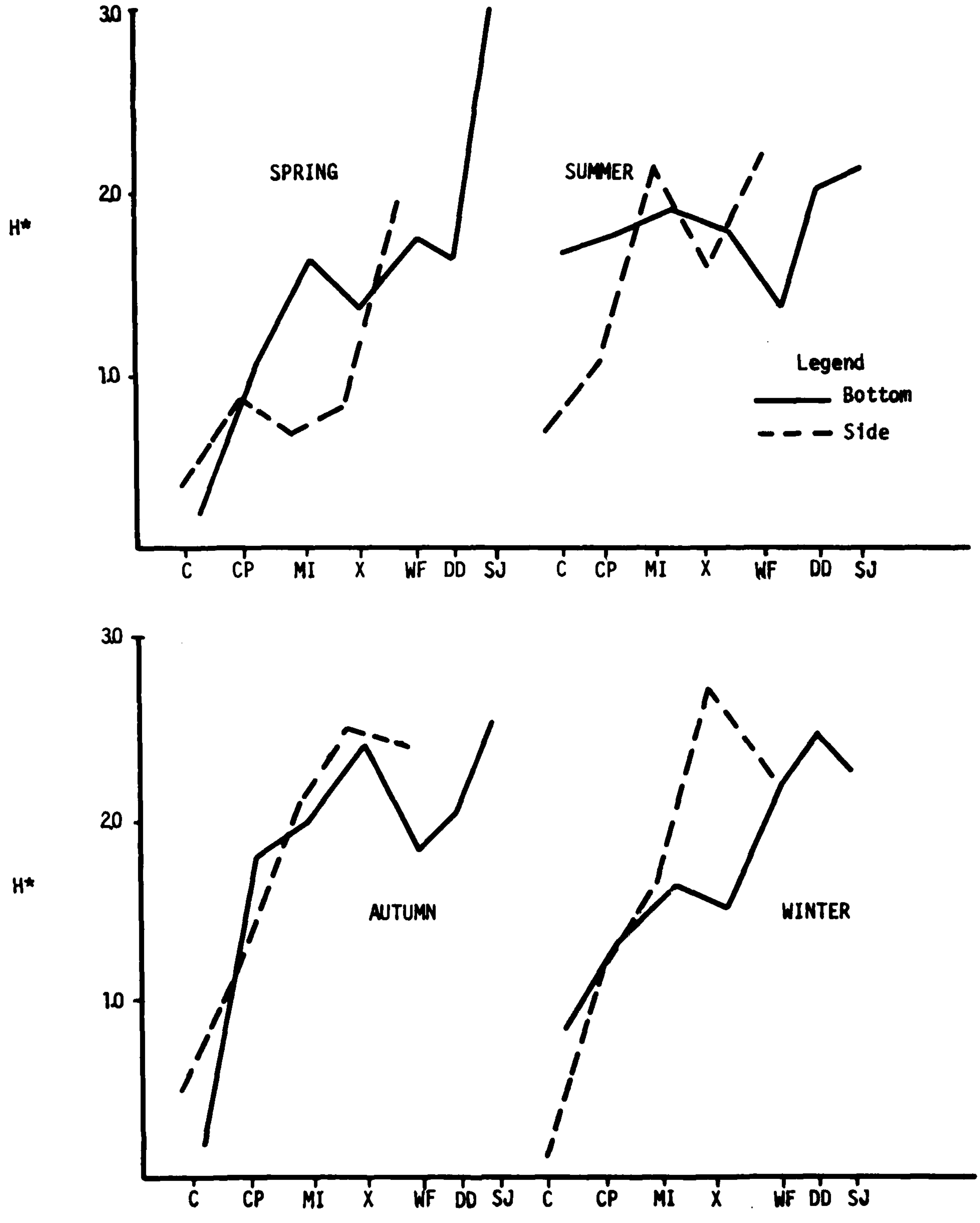


Figure 43. Diversity (H*) values for subtidal stations by season, Grays Harbor, Washington, 1980-1981.

higher H* values than the side; at Whitcomb Flats the channel side had higher H* values than the bottom. At other sites where samples were collected both at the channel bottom and channel side, the area having the highest H* values varied with season, however, diversity values generally peaked in autumn on both the side and channel bottom stations. Diversity was generally lowest in spring before starting to increase.

Some fluctuations of diversity values at some sites were possibly caused by dredging activity at or near that site. Abundance was the key component in fluctuations in diversity values, especially at ineer harbor sites. Inversely, abundance had less affect at sites DD and SJ where species richness dramatically increased (Appendix G, Table 15).

Low salinity probably contributed to low diversity at Cosmopolis subtidal stations. Factors affecting the somewhat higher H* values in autumn might be decreased dredging activity, changes in the relative proporations of species abundances due to reporductive patterns and mortality, and population response to higher salinity values at inner harbor sites.

Abundance

Intertidal

In spring, the Marsh Establishment Site had the highest abundance of invertebrates. During all other seasons, Cow Point had highest abundance (Fig. 44). Moon Island had the lowest abundance during each season. In general, moving either east or west from the site of highest invertebrate abundance (the Marsh Establishment Site in spring and Cow Point in all other seasons), total abundance steadily decreased.

Annelids were the most important faunal group contributing large populations to the benthic invertebrate community. This group contributed 30-80% of the total at every site (Fig. 45).

The 2.14 m stations generally had the highest density of invertebrates; the only exception was at the Marsh Establishment Site, where the 1.22 m station had the highest density of invertebrates. This resulted from distribution of annelids, which exhibited a similar pattern of peak abundance to that described above and the numerically dominant faunal group at the 2.14 m station. At 1.22 m, annelids were normally the numerically dominant group, while crustaceans were also abundant. At the MLLW stations, crustaceans were the numerically dominant group at all sites except Moon Island. However, while crustaceans constitute a larger percentage of the total density of invertebrates at MLLW, they do not always reach peak densities at this station. Annelids and crustaceans acount for at least 98% of the total number of organisms found at all sites except Moon Island, hwere clams accounted for 14% of the total.

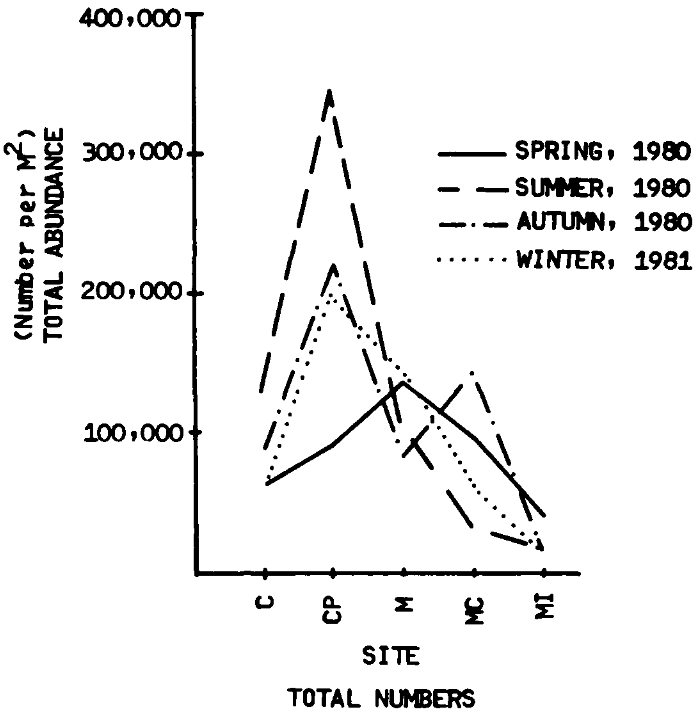


Figure 44. Total abundance of invertebrates by season for all intertidal sites, Grays Harbor, Wa. 1980-81.

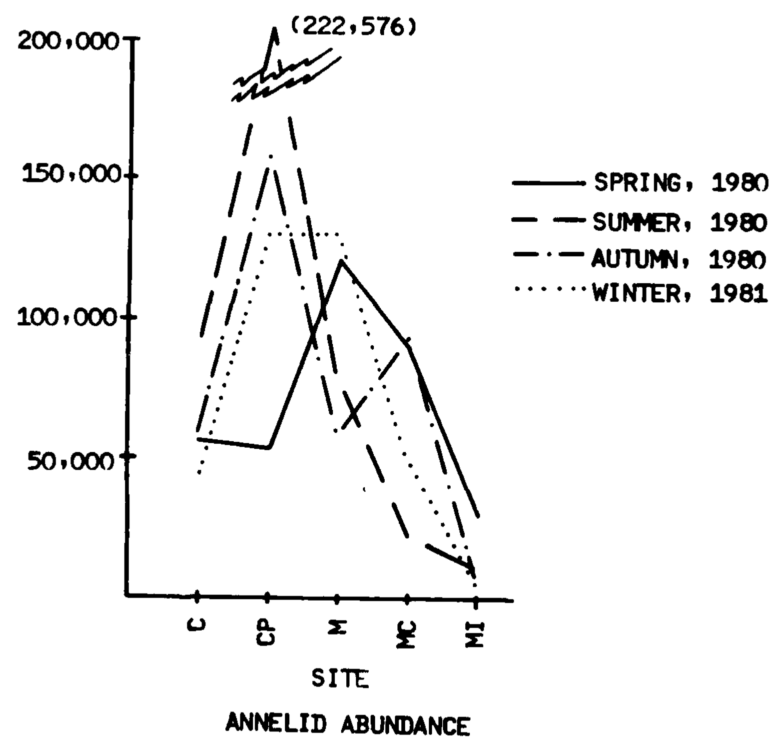


Figure 45. Total abundance of annelids by season for all intertidal sites, Grays Harbor, Wa. 1980-81.

Seasonal patterns of abundance varied according to site. Cosmopolis and Cow Point both had peak abundances in summer, while the other sites peaked in different seasons. When total number of organisms at all sites is considered, peak abundance occurred during summer, and the lowest abundance occurred during spring.

Subtidal

The channel-side station at Cosmopolis had the highest abundance of invertebrates during each sampling period except spring, when the channel-bottom station had a slightly higher abundance (Figure 46). Other stations which generally had high abundances were the channel-bottom at Cosmopolis and the channel-side at Moon Island. South Jetty also had high numbers of organisms including barnacles. Stations with consistently low abundance or organisms included the channel-side stations at the Crossover Channel and Whitcom Flats, the Deepwater Disposal site, and the channel-bottom station at Moon Island.

High abundances of invertebrates at Cosmopolis and Moon Island channel-side stations corresponded with high numbers of *Corophium* spp. At Cosmopolis, Corophium spinicorne, which

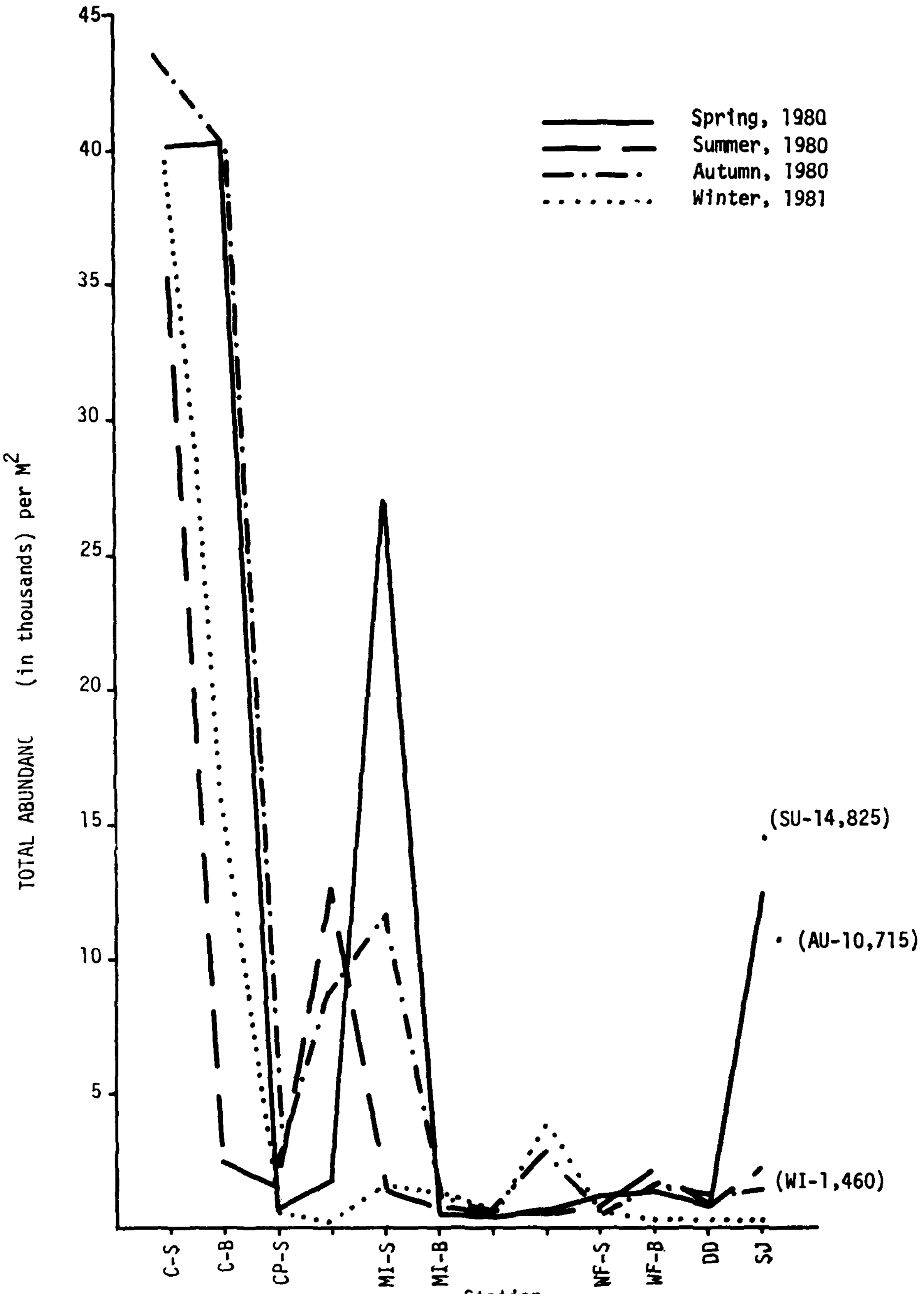


Figure 46. Invertebrate abundance for subtidal stations by season, 1980-81, Grays Harbor, Washington, SJ points only indicate abundance including barnacles.

normally attaches it's tubes to the sides of cobbles and gravel, was found to number between 30,300 and 39,300 per m^2. At Moon Island, 3 species of *Corophium* were present: *C. brevis*, *C. salmonis*, and *C. spinicorne*. However, the abundance of *Corophium* at this station fluctuated drastically with season. Density of *Corophium spinicorne* was extremely high at the Cosmopolis channel-bottom station in winter. During the remainder of the sampling periods, the high numbers of invertebrates at this station was related to the high number of oligochaetes.

Patterns of crustacean and annelid abundance were similar to those of total abundance. Stations in the inner harbor area (from Moon Island eastward) generally had higher numbers for both faunal groups (Figures 47 and 48). This was especially true for annelids, which was perhaps related to the abundance of fine sediments and corresponding high percentages of total volatile solids found at inner harbor stations.

Abundance of clams showed large fluctuations among stations (Fig. 49). No clams were found at the Cosmopolis site. Salinity was apparently too low for clams to regularly occur at Cosmopolis Site.

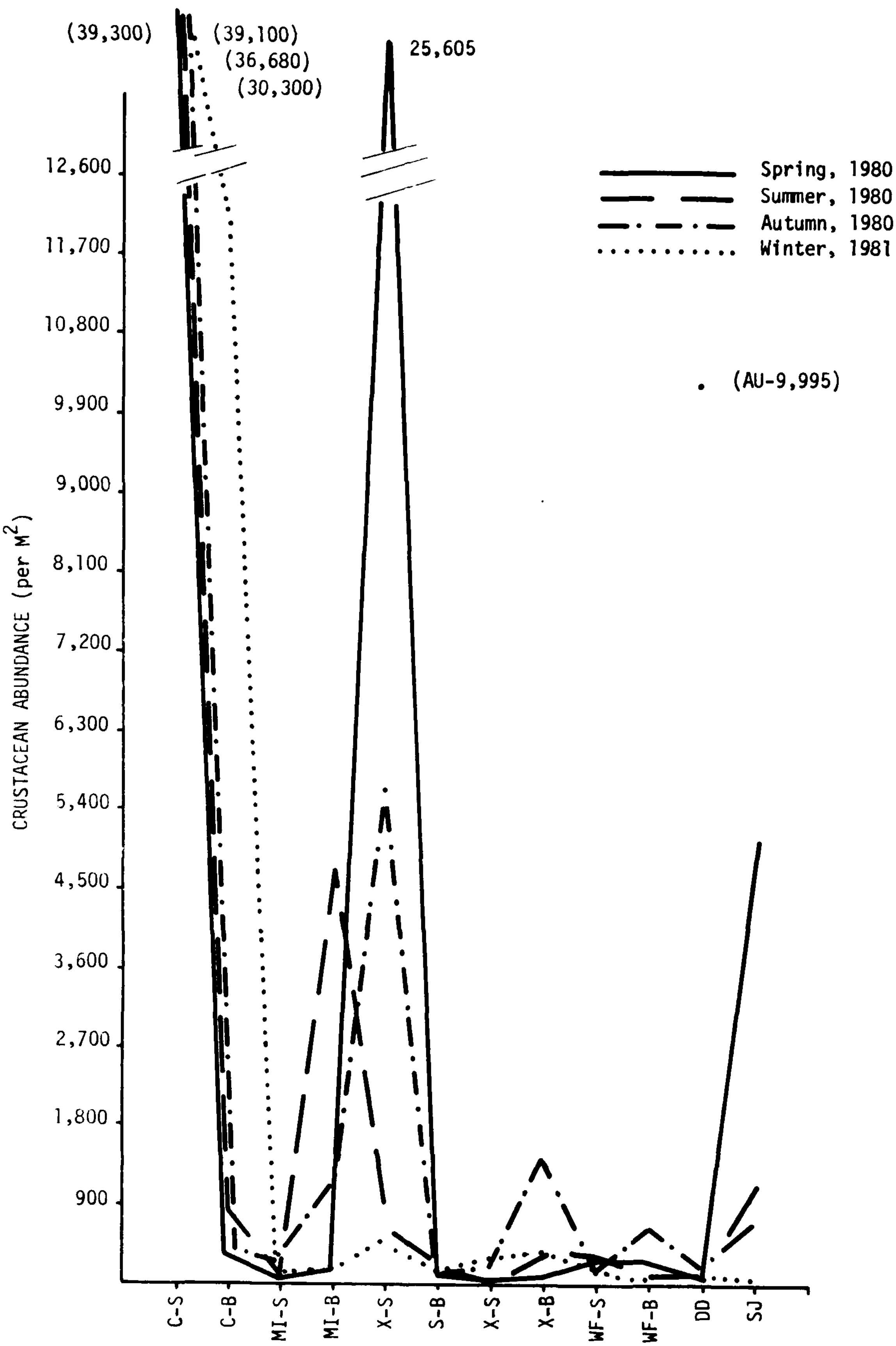


Figure 47. Crustacean abundance for subtidal stations by season, Grays Harbor, Washington, 1980-81, SJ points only indicate abundance with barnacles.

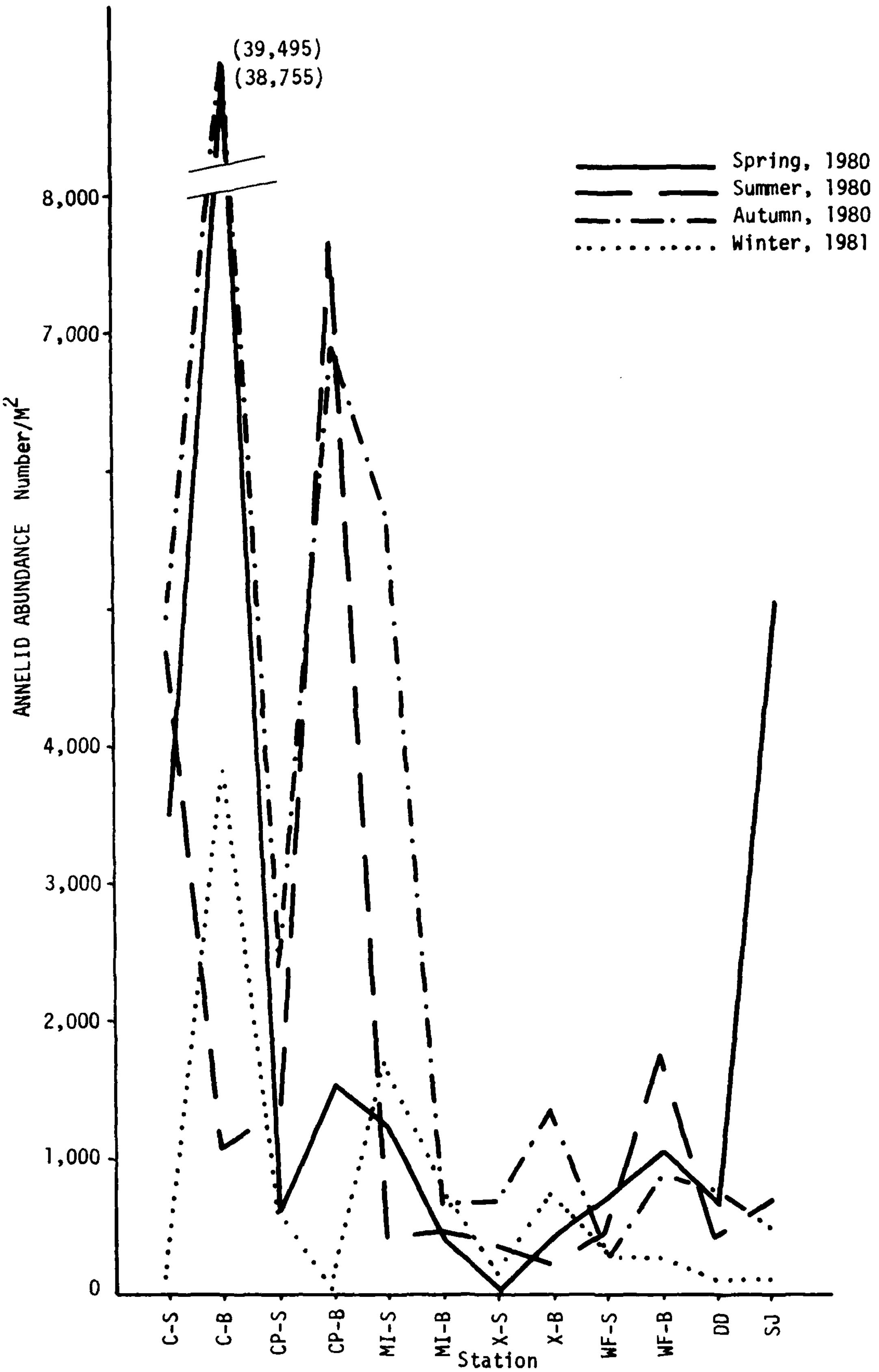


Figure 48. Annelid abundance for subtidal stations by season, Grays Harbor, Washington, 1980-81

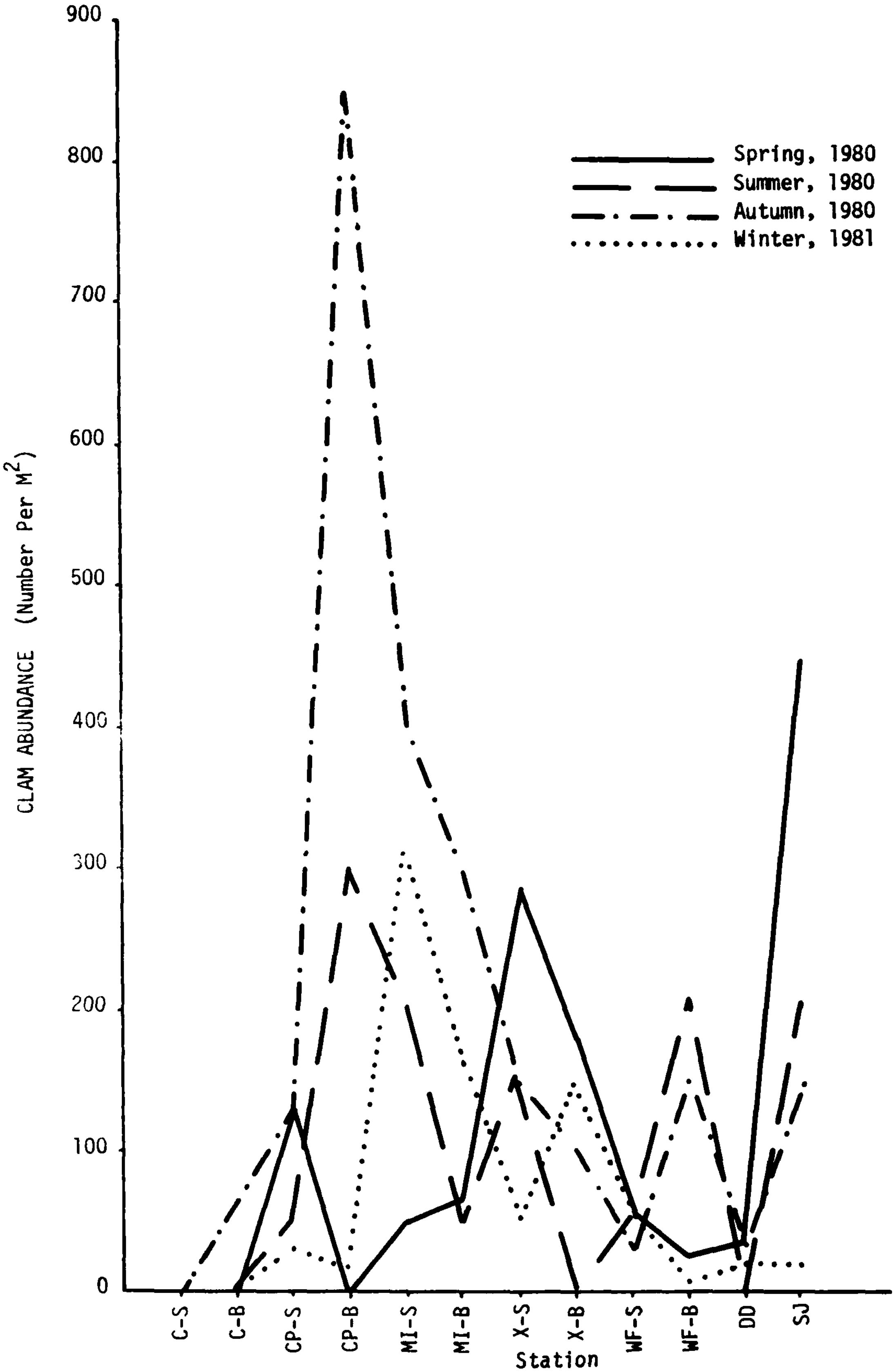


Figure [illegible]. Clam abundance for subdidal stations by season, Grays Harbor, Washington, 1980-81

Biomass

Intertidal

Biomass measurements tended to fluctuate drastically among core samples. This reflects the patchy distributions of most invertebrate populations. Additionally there was often little correlation between station or site abundance and biomass. For example, Cow Point had its highest seasonal abundance of organisms during summer, at the same time biomass was lowest. Such patterns can occur as a result of the appearance of large numbers of juveniles or small organisms during a particular season which contribute little biomass.

Total biomass (both infaunal and epifaunal) was highest at Cow Point and lowest at Cosmopolis during each season, except in winter, when biomass of invertebrates was slightly lower at Moon Island than Cosmopolis. Biomass of the remaining sites varied with season. Moon Island generally had a lower total biomass of invertebrates than the Marsh Establishment and Marsh Control sites (Appendix D, Tables 1-5). When epifauna are excluded from biomass computations, highest biomass occurred in spring, while lowest biomass occurred during summer. When epifauna (barnacles, fish, crabs, and shrimp) are included, total biomass was highest in summer, attesting to the important contribution of epifauna (primarily barnacles) to biomass, especially at Cow Point.

While clams were an important component of the biomass at Moon Island, Marsh Establishment, Marsh Control sites and the MLLW station Cow Point site, it is difficult to accurately assess their biomass from core samples. If biomass of clams per unit area are computed from box sample data rather than core samples, the contribution of clams to total biomass becomes much more significant, especially at Moon Island. Using this method, Moon Island was the site with the highest total biomass during all four sampling periods (Figure 50). Clam biomass is attributed mainly to Mya arenaria. Cosmopolis site, which has no Macoma blathica or Mya arenaria, had the lowest total biomass in each season. Cow Point, which had no clas at the 1.22 m and 2.14 m stations, had total biomass values similar to those of Marsh Establishment and Marsh Control Sites.

No clear trends in biomass were evident throughout intertidal sites by elevation. Three sites had highest biomass at the 2.14 m stations (Cow Point, Marsh Establishment Site, and Marsh Control Site), while the remaining 2 sites had highest biomass at the MLLW stations.

Total biomass tended to be highest in winter and lowest in summer when biomass of clams calculated from box sample data was used for total biomass figures. Biomass of clams was highest at sites with highest salinity (Moon Island, Marsh Establishment Site, and Marsh Control Site), and were most abundant at

BIOMASS - I

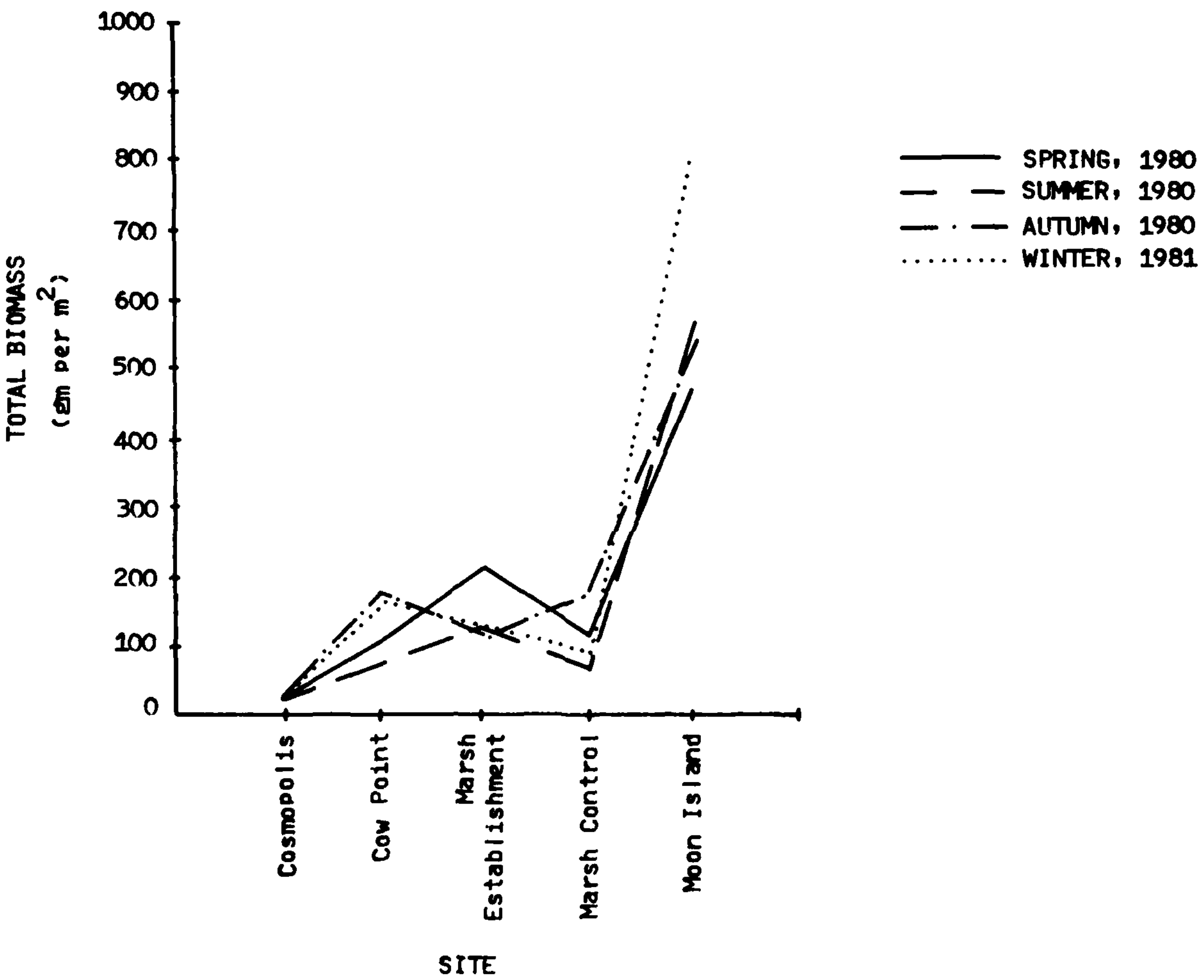


Figure 50. Total invertebrate biomass* by season for all intertidal sites, Grays Harbor, Washington, 1980-81.

*Excludes epifauna; uses box data for clams.

the 2.14 m and MLLw stations. At these sites, clams were the major contributor to total biomass. As a result, there was a general trend toward increasing total biomass as salinity increased (Fig. 49). Biomass of annelids was fairly constant from site to site (Fig. 51). Biomass of crustaceans was generally low on all sites, except at the 1.22 m and 2.14 m stations at Cow Point (Fig. 52), where large numbers of Gnorimosphaeroma luteum were found.

Subtidal

Total biomass of infaunal organisms (e.g., barnacles, crabs, and shrimp excluded) showed no clear trends from river mouth to harbor entrance (Figure 53). There were substantial fluctuations in total biomass from one sampling period to the next. Exceptions were the Cosmopolis channel-side station, which had high biomass during all 4 sampling periods (greater than 9.9 g per m^2), and the Whitcomb Flats channel-side, and Deepwater Disposal stations, which had very low biomass (less than 6 g per m^2) throughout the year. Necks from several large clams were collected at the South Jetty indicating the presence of a large clam population. Since this population was not sampled, biomass at this station was probably underestimated. When barnacles, crabs, and shrimps are included in total biomass calculations, highest biomass occurred at Cosmopolis channel-side and South Jetty with one exception. The exception was

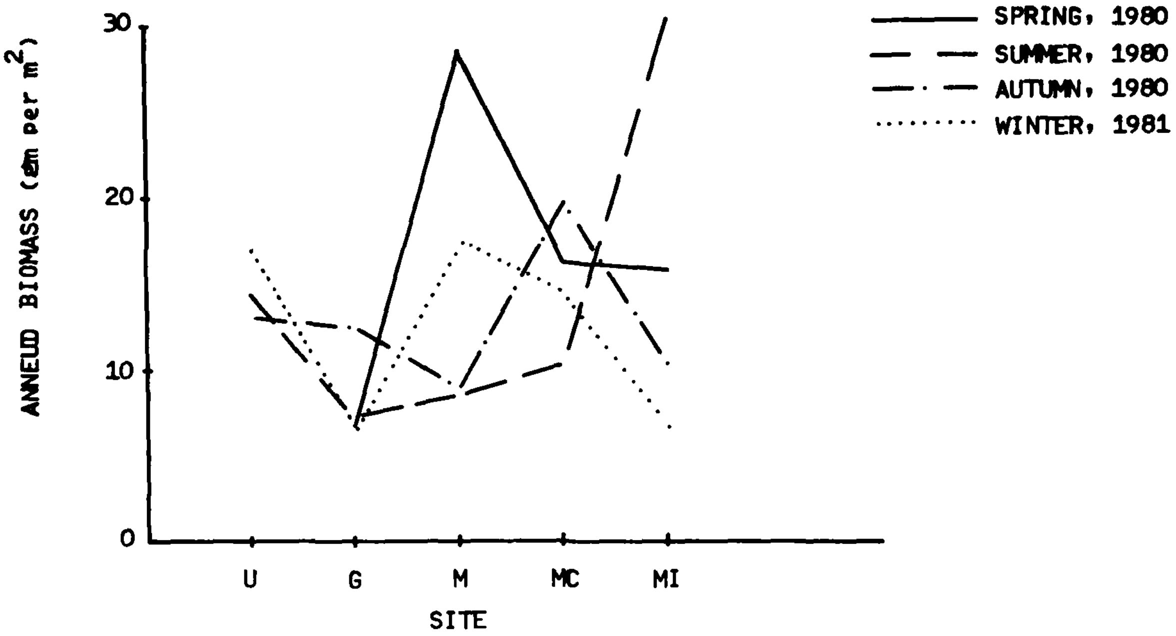


Figure 51. Total annelid biomass by season for all intertidal sites, Grays Harbor, Washington, 1980-81. High-Spring 82.6 g/m^2, Low-Winter 61/1 g/m^2.

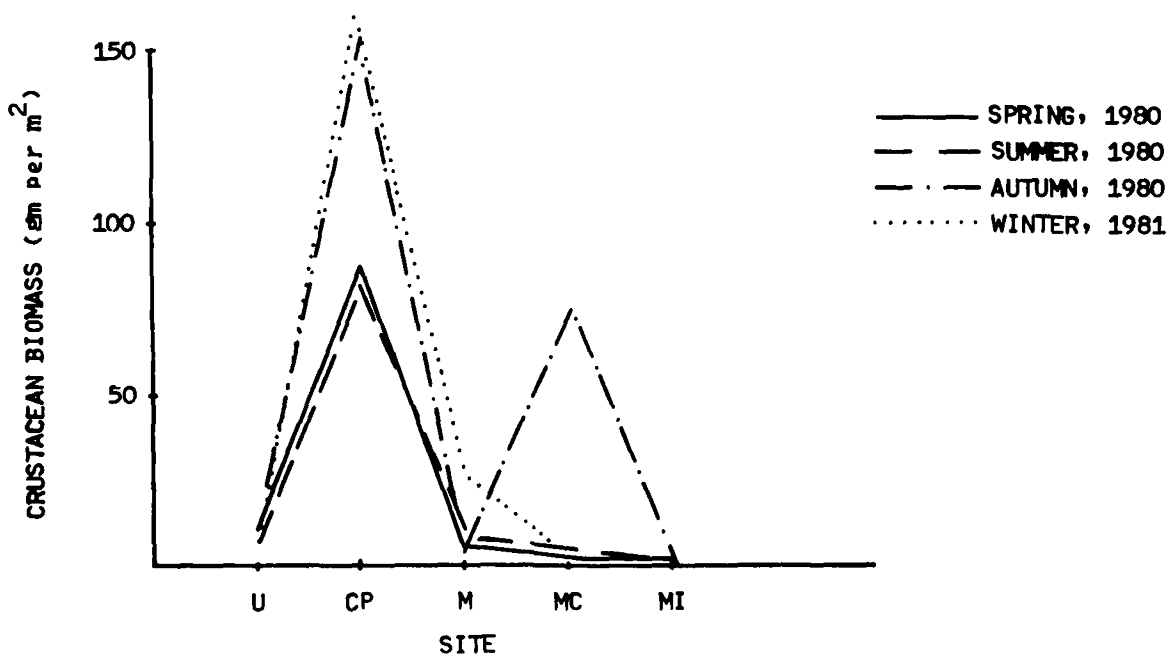


Figure 52. Total crustacean biomass (excluding barnacles) by season for all intertidal sites, Grays Harbor, Washington, 1980-81. High-Autumn 243.6 g/m^2; Low-Summer 108.7 g/m^2.

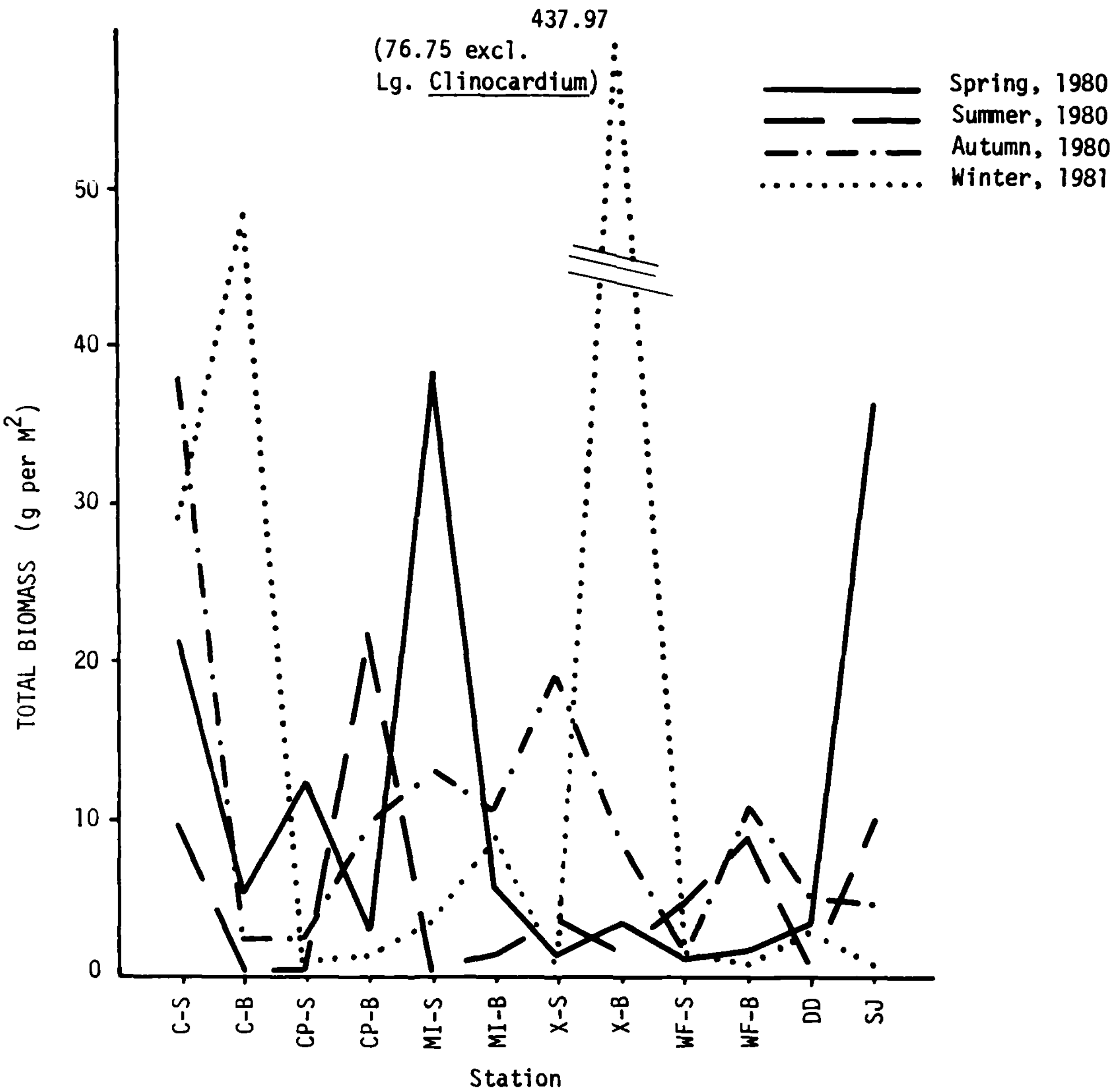


Figure 53. Invertebrate biomass (g per M^2) excluding barnacles, crabs, and shrimp, for subtidal stations, Grays Harbor, Washington, 1980-81.

channel-bottom station at the Cross-over Channel site during winter, which had the highest biomass of any subtidal station during any season (438 g per m^2). The bulk of this biomass was contributed by a single large cockle. However, this station had high biomas even without inclusion of this cockle (361 g).

Since most clams are long-lived organisms relative to infaunal crustaceans and annelids, they may be more sensitive to impacts by dredging. At sites affected by dredging, only one large clam was found. At Cosmopolis, 3 clams (Macoma sp.) were found in autumn. At the channel bottom, however, biomass was negligible (.01g/m^2).

Total biomass was highest in winter and lowest in summer. This pattern held true regardless of whether or not epifauna was included in the computations (Figure 54).

Biomass of annelid was highest in winter, largely due to occurrences of high biomass of annelids at 2 stations (the Cosmopolis channel-bottom and Cross-over Channel channel-bottom stations). However, 6 stations had their highest biomass of annelids in autumn (Fig. 55). Biomass of annelids was lowest during spring and summer. The outer harbor sites (Whitcomb Flats, Deepwater Disposal, and South Jetty sites) all had consistently low biomass of annelids (less than 3.6 g per m^2), while 6 of 8 inner harbor stations had at least one season where biomass of annelids was greater than 10 g per m^2. This trend may in part be due to the inability of the

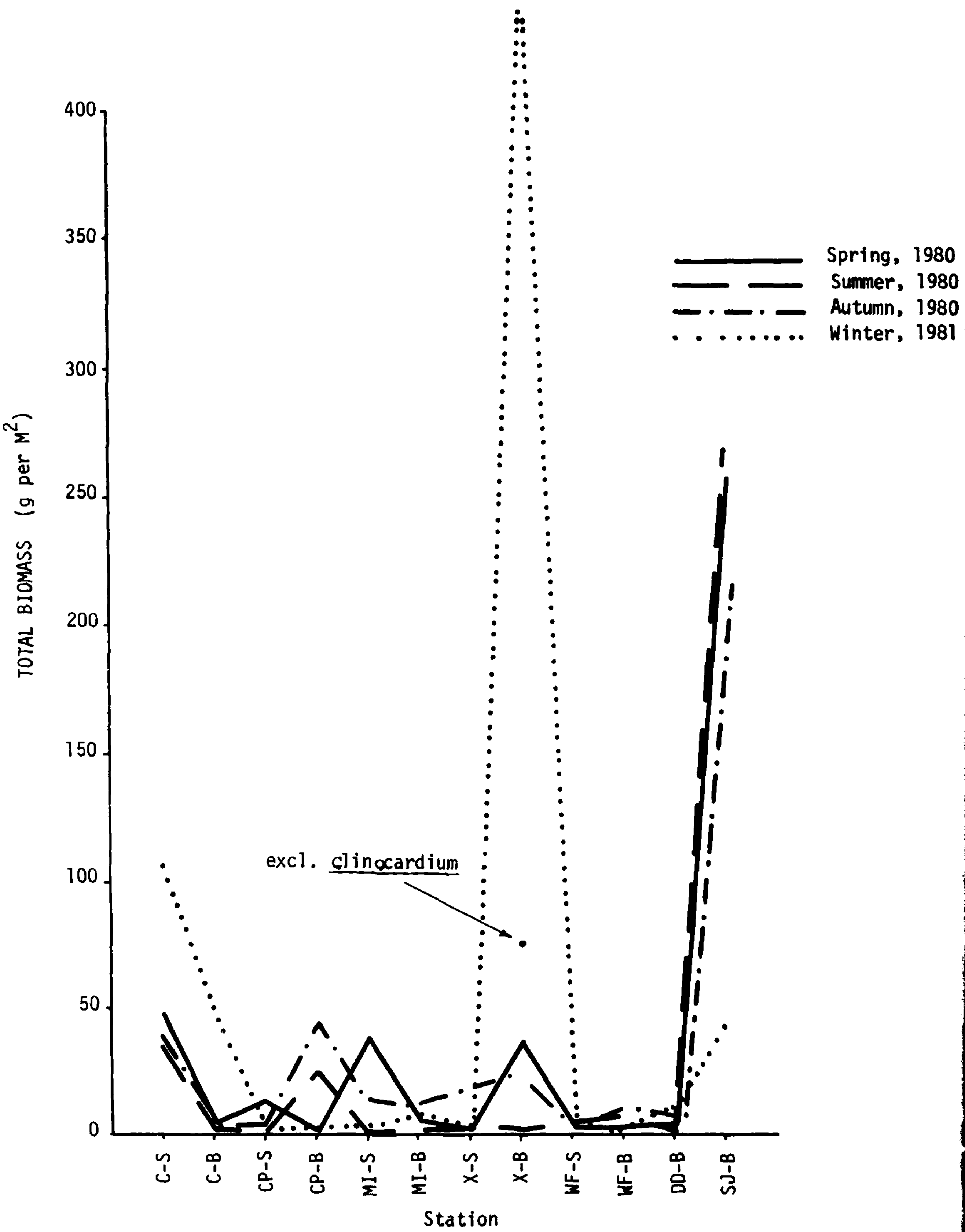


Figure 54. Invertebrate biomass (g per M^2), including barnacles, crabs, and shrimp, for subtidal stations by season, Grays Harbor, Washington, 1980-81.

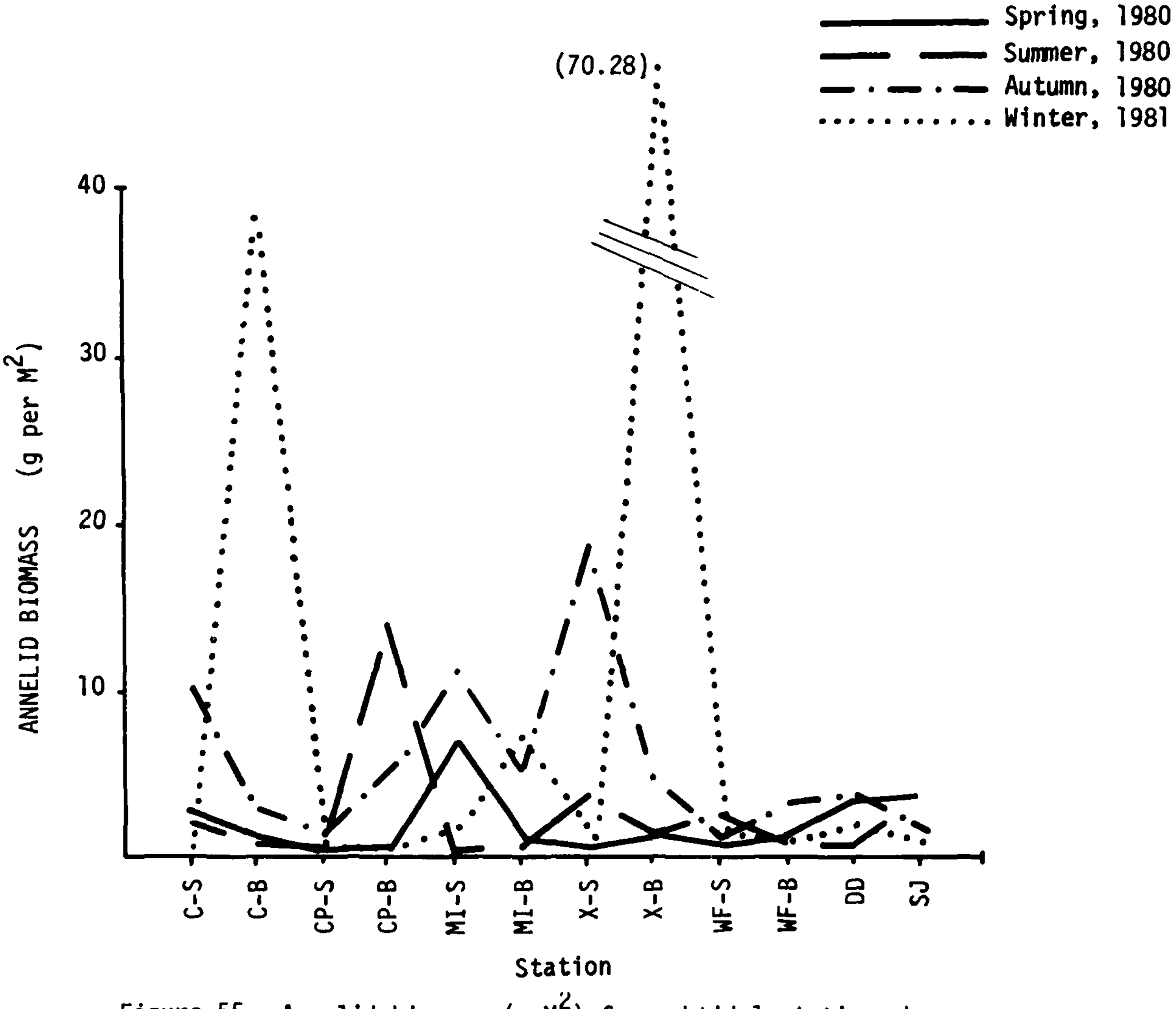


Figure 55. Annelid biomass (g-M^2) for subtidal stations by season, Grays Harbor, Washington 1980-81

van Veen grab to sample sand and cobble sediments efficiently.

Biomass of infaunal crustaceans was generally lower than that of annelids. High biomass of crustaceans at the Cosmopolis channel-site station was due to the abundance of Corophium spinicorne at that station (Fig. 56 and 57).

Barnacles made important contributions to biomass at 2 sites: South Jetty and Cosmopolis channel-side stations. Other faunal groups made significant contributions to biomass (greater than 1 g per m^2) on only 4 occassions: 1) Crossover Channel or channel-bottom station during winter and autumn (5.65 and 3.23 g per m^2, respectively), due mostly to nemerteans; 2) the Whitcomb Flats channel-bottom station in autumn (3.63 g per m^2), due to sand dollars and nemerteans; and 3) at the Cosmopolis channel-bottom station during spring (1.29 g per m^2) due to nemerteans and egg masses.

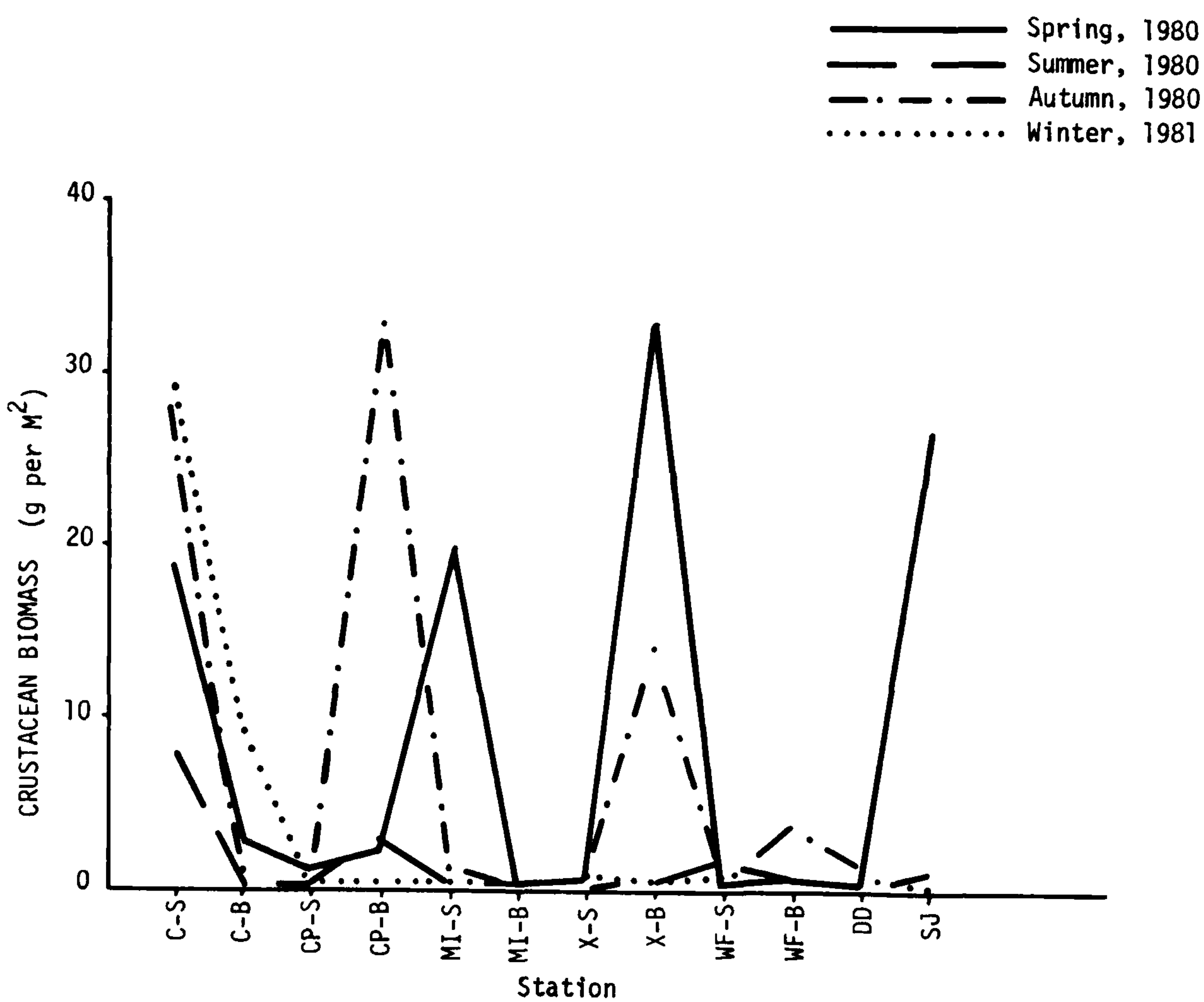


Figure 56. Crustacean biomass (g per M^2) including crabs and shrimps (excludes barnacles) for subtidal stations by season, Grays Harbor, Washington, 1980-81.

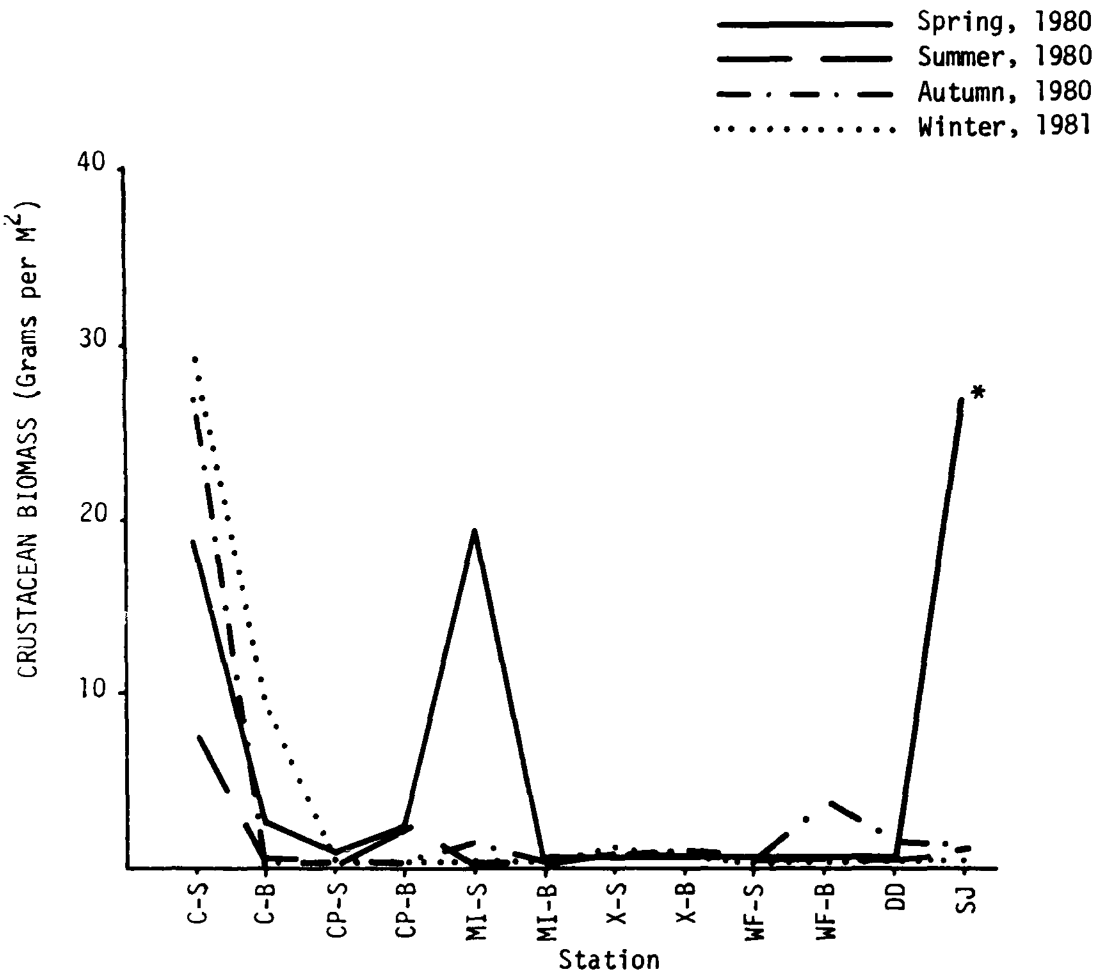


Figure 57. Crustacean biomass (g per M^2) excluding crabs and shrimps (excluding barnacles) for subtidal stations by season, Grays Harbor, Washington, 1980-81.

*This point does include crabs.

Multivariate Analysis

Intertidal

Spring: The dendrogram for the spring intertidal sampling broke into 3 primary groups (Fig. 58). The first group (Group A) consisted of all the Cosmopolis and Cow Point stations. Salinity may have been the major factor causing this grouping. These stations were those most heavily influenced by freshwater flow. The substrate at most of these stations contained coarse sediments (sand and gravel); however, the 2.14 m station at Cosmopolis, consisted primarily of silt, indicating sediment type was perhaps not as important in terms of clustering as salinity. This group is sub-divided into 2 sub-groups, the 1.22 m station at Cow Point comprising 1 sub-group and the other 5 stations the second sub-group. The stations in Group A were characterized by high abundances of *Manayunkia aestuarina*, *Corophium spinicorne*, and oligochaetes. Except CP 1.22 m station, the invertebrate community here was dominated by the crustaceans *Engammarus confervicolos* and *Gnorimosphaerama luteum*. Groups B and C contained the stations occurring in more saline areas. These stations generally also had finer sediment types (fine sand, silt, and clay). Groups B and C split roughly according to station elevation, with Group B containing higher stations.

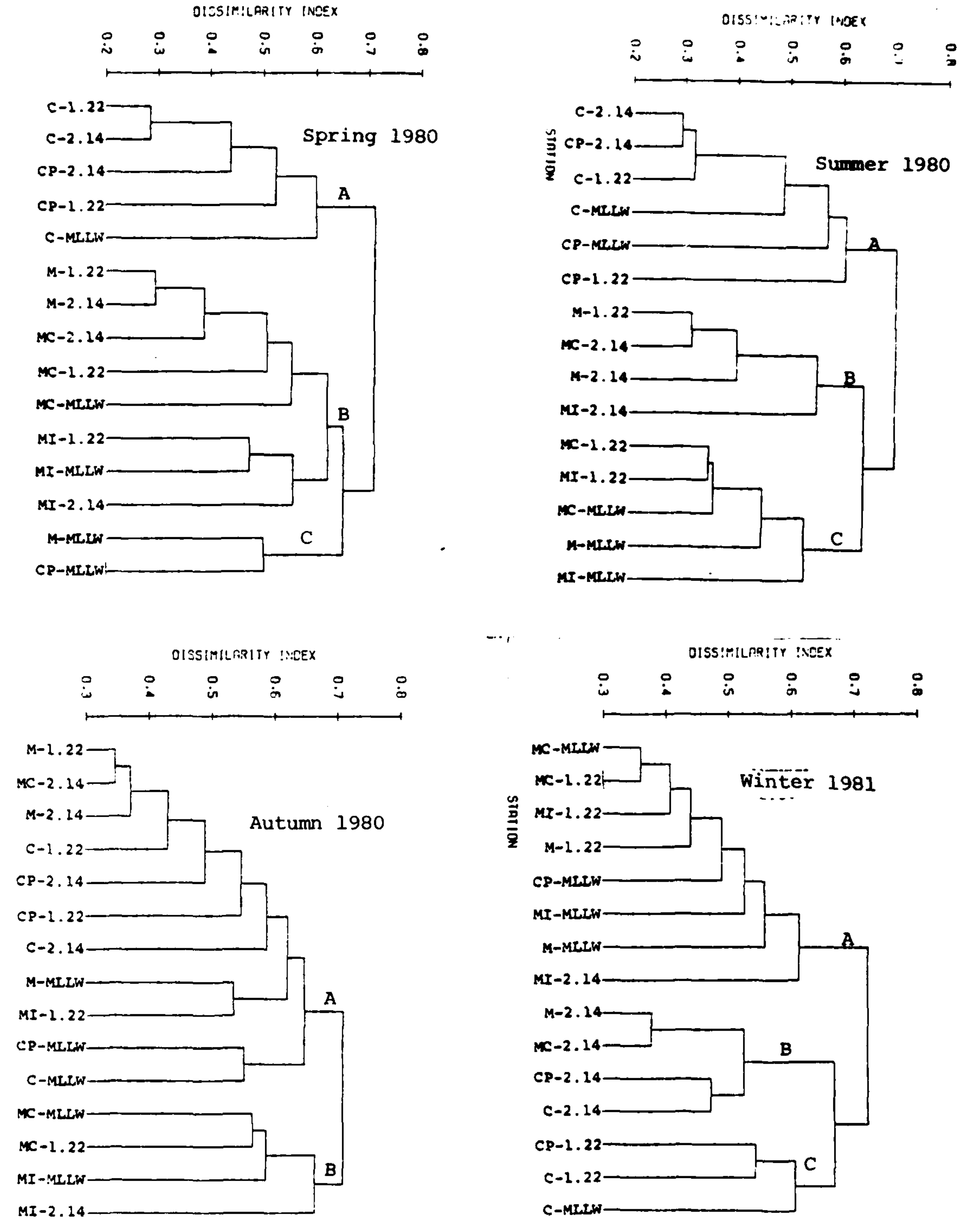


Figure 58. Cluster analysis dendograms for intertidal stations, by season, Grays Harbor, Washington, 1980-1981.

Summer: The dendrogram for summer intertidal sampling broke into 3 main grups, 2 of which could reasonably be broken into sub-groups. Group A contained all the Cosmopolis and Cow Point stations, with the exception of the MLLW station at Cow Point. Again, these stations were characterized by low salinity and, except for the 2.14 m station at Cosmopolis, had a significant gravel or cobble component in the sediment. The MLLW station at Cosmopolis was separated from the rest of the stations in the group, forming a separate sub-group. This was caused by the abundance of the annelid worm Polydora hamata at this station, which was not a major component of the benthic community at any other station. Groups B and C contain stations characterized by higher salinity. The MLLW station at Cow Point was an exception to this pattern. Group B. can be divided into 2 sub-groups. Stations in sub-group 1 contain soft (primarily silt and clay), unconsolidated sediments. Stations in sub-group II, the 3 Moon Island stations, were the western-most of the intertidal stations and therefore, had the highest salinities. In addition, sediments here had a significant sand component and were compact and firm. Group C included MLLW stations from Marsh Establishment and Cow Point Sites. High numbers of barnacles were present on both these stations. Presence of gravel and cobble substrate on these sites is believed to be the primary reason for high barnacle populations.

Autumn: Three major groups occurred in the dendrogram for autumn. All stations in Group A, with exception of the MLLW station at Cow Point, are from more saline sites. The 2.14 m station at Moon Island represents a separate sub-group within Group A, and appears to be a fairly unique station. Sediment at this station was fine and while sediments at other stations were either finer; (substrate at MI-1.22 Mc-1.22, MC-MLLW, and M-1.22 stations were silt and clay) or were coarser M-MLLW, CP-MLLW, MI-MLLW were cobble and gravel). The invertebrate community at CP-MLLW station was composed of 3 species belonging to 2 groups of polychaete worms and clams. All other stations in this group had more diverse community structures. Group B contains the 2.14 m stations from all sites with the exception of Moon Island. All these stations had extremely high abundances of Manayunkia aestuarina. Thus, elevation seemed to play an important role in determining station groupings during autumn. Group C contained the mid and lower intertidal stations from Cosmopolis and Cow Point, with the exception of CP-MLLW. All these stations were characterized by low salinity and large gravel and/or cobble fractions in the sediment. Few barnacles occurred at these stations.

Winter: The dendrogram for winter sampling period was the most difficult to interpret. Five station groups were identified. Group A contained the 2.14 m and 1.22 m stations at Cosmopolis, Cow Point, and Marsh Establishment Sites, and the 2.14 m station at Marsh Control Site. A combination of salinity and elevation is the basis for grouping these stations together. Stations in the other groups were linked together by high dissimilarity values, so their groupings are somewhat more tenuous. The 2 stations in Group B seem difficult to tie together. Perhaps the most obvious common factor in this group was presence of hard-packed sediments with a thin film of soft silt and clay overlaying them.

Group C included the MLLW stations at Cow Point and Cosmopolis. These stations had similar substrate types consisting of cobble, gravel, sand, and mud. High river flows during winter probably reduced salinity at Cow Point to near zero, comparable to salinity at Cosmopolis. Group D contained only lower elevation stations from the westernmost sites. Group E contained only the 2.14 m station at Moon Island, which was the only intertidal station with a fine sand substrate.

Summary: Salinity, elevation and sediment type all appear important in determining the arrangement of clusters. The relative importance of each factor changes with the season. Salinity appeared to be extremely important during spring and summer, while elevation appeared to be most significant during autumn and winter. Perhaps this occurred because of seasonal changes in tidal flux from daytime low tides and hot weather during summer, to nighttime low tides and colder weather during winter. High freshwater flows from the Chehalis River greatly reduced salinity throughout the inner harbor area during winter, diminishing differences in salinity between sites, and reducing the importance of salinity in determining clusters during winter.

The MI-2.14 station was, perhaps, the most unique, having high dissimilarity values year round. Probably as a result of the unique and stable sediment present on this site, as this was the only station with a substrate composed primarily of fine sand.

The clustering technique employed in this study is most influenced by the distributions of numerically dominant species. The polychaete Manayunkia aestuarina and the amphipods Corophium spp. were therefore important in the grouping of stations. The distribution of Manayunkia appeared to be influenced more by salinity and elevation than changes in substrate. Distribution of Corophium spinicorne and Corophium salmonis appeared to be influenced strongly by sediment type, as well as elevation and salinity. Other organisms which were important in affecting the pattern of clustering were obligochaetes, the polychaete *Streblospio benediciti*, and the clam *Macoma balthica*.

Multivariate Analysis

Subtidal

Spring: Two major station groups were apparent from the dendrogram for the spring sampling (Fig. 59). These groups corresponded well with geographic location within the harbor. Group A constituted the outer harbor stations, with the single exception of the channel-side station at Moon Island. Group B encompassed the remainder of the inner harbor stations.

The stations within each group had high dissimilarity values, thus, the groupings do not represent any great likenesses in benthic community composition. Within each group, however, certain stations formed more closely related sub-groups. One sub-group in Group A contained stations having high salinity and sediments composed primarily of sand. The polychaete *Magelona sacculata* was the dominant organism at each station in this sub-group. The sub-group including X-S and X-B, stations had similar sediment composition and salinity regimes. The invertebrate community at MI-S was dominated by *Corophium* especially C. brevis. Barnacles, however, were the most abundant invertebrate at the South Jetty site. The first sub-group in Group B contained 2 stations which both had high percentage composition of oligochaetes and the polychaete *Streblospio benediciti*. The remaining stations in this group were dissimilar enough to each be considered in a separate sub-group. The 3 remaining stations had only 1 or 2 species components to their invertebrate community structure. C-B was almost exclusively populated by Oligochaetes (90% of total population). The invertebrate community at C-S consisted of *Corophium spinicorne* and

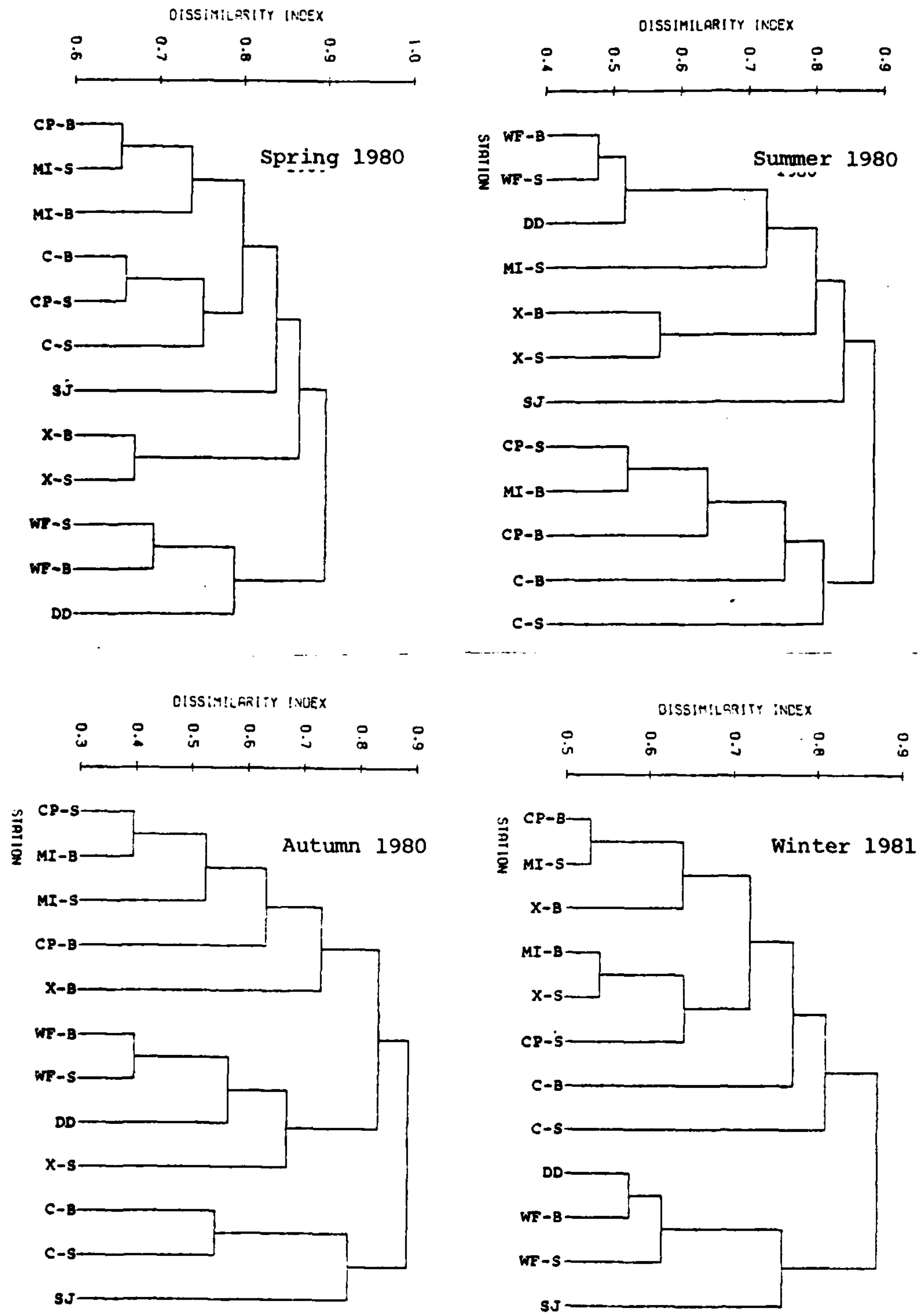


Figure 59. Cluster analysis dendograms for subtidal stations, by season, Grays Harbor, Washington, 1980-1981.

Polydora hamata, 78 and 12% respectively of the total population. Station CP-B consisted of Polydora ligni, 76% of total, plus miscellaneous organisms.

Summer: Dissimilarity values were generally higher in summer than during any other season. However, if the dendrogram is broken down on a gross level, 2 groupings are evident. Group A contains 4 sub-groups: two of these sub-groups contain the stations from the innermost portions of the harbor, where low salinity predominates. The other sub-groups contain stations farther out into the harbor, where salinity is higher. Most surprising is the inclusion of the South Jetty station in this group. This primarily resulted from large numbers of barnacles at both the South Jetty and the Cosmopolis channel-side stations.

Group B is comprised of those outer harbor stations whose sediment type consisted of fine sand. During summer the benthos at these stations was characterized by the polychaetes *Ophelia limacina*, *Euzonus mucronata*, and *Magelona sacculata*, and the amphipod *Paraphoxus milleri*.

Autumn: Dissimilarity levels were still high during autumn. Thus, all stations had somewhat unique benthic communities. Two major groups are apparent in the dendrogram. Group A contained the inner harbor stations, including both stations at the Crossover Channel site. Four sub-groups were present in Group A. The arrangement of stations into sub-groups was quite different than that resulting from the summer sampling. X-B station was the most interesting in this respect. The invertebrate community was dominated by entirely different organisms in summer than in fall (Table 8). For example, Corophium spinicorne accounted for 36% of the population in summer and was totally absent in the autumn. Similarly 3 species contributed 5% or more to the total population during fall and yet were not found during other seasons (Table 8). Similar changes in the biota of other stations can be noted, although X-B illustrates the seasonal variability that occurs within this harbor. Group B was comprised of the outer harbor stations. The high dissimilarity of the South Jetty station to the other stations in this group necessitated the designation of 2 sub-groups. The South Jetty station was grouped with the other outer harbor stations.

Winter: Dissimilarity levels were lower during winter than any other season. Three station groups were apparent. Group A contained all the inner harbor stations except the 2 Cosmopolis stations. Group B contained 3 of the 4 outer harbor stations (the 2 Whitcomb Flats and the Deepwater Disposal Site stations), as well as the channel-side station from the Crossover Channel. This latter station was largely incorporated into this group because of influx of the amphipod Paraphoxus milleri. It was dissimilar enough from other stations in this group to be considered in a separate sub-group by itself. Stations in this group were characterized by 6 or 7 species each supplying less than 20% of the total population. Group C contained the 2 Cosmopolis stations and the South Jetty station. The Cosmopolis stations had extremely high numbers of the amphipod Corophium spinicorne, while the Cosmopolis channel-side and South Jetty stations had an abundance of barnacles.

Summary

The subtidal stations generally had higher dissimilarity values than the intertidal stations. Thus, subtidal stations possess more unique benthic communities. This is not unusual considering the wider geographic area covered by the subtidal sample stations relative to the intertidal sample stations.

Dissimilarity levels gradually increased during the spring and summer samplings, before decreasing in autumn and winter. The reasons for this pattern are unknown. The cause may lie in a variety of factors, both biotic (e.g., reproductive and distributive patterns of key species) and abiotic (e.g., salinity regimes).

The most consistent pattern of station grouping over the four sampling periods was the breakdown into inner harbor versus outer harbor stations. Three of the four outer harbor stations (the Whitcomb Flats stations and the Deepwater Disposal Site station) clustered fairly closely during each season. While salinity differences between the inner and outer harbor probably account for much of the difference in benthic community structure, many other factors are confounded with the salinity gradient. Examples are decreasing silt and increasing sand fractions in the sediments, decreasing percentage of total volatile solids, decreasing pollution and increasing wave exposure moving from east to west along the navigation channel. The importance of substrate type is illustrated by the position of the South Jetty and Cosmopolis channel-side stations in the summer and winter dendrograms, where presence of barnacles were significant in making these stations less dissimilar. Had barnacles been excluded from the cluster analyses, the South Jetty station would have consistently clustered with the other outer harbor stations.

Generally, the Cosmopolis, Cow Point, and Moon Island stations comprised the inner harbor stations. Whitcomb Flats, Deepwater Disposal Site and South Jetty (especially when barnacles were excluded) stations constituted the outer harbor stations. Oceanic influences predominated at outer harbor stations, where absence of strictly estuarine species such as Corophium spp., Eogammarus spp., Mya arenaria, and Macoma balthica was evident. Instead, species "adapted" to more saline waters such as Dendraster excentricus, Siliqua sp., Archaeomysis grebnitzskii, and Magelona sacculata began to crop up at these stations.

The stations at the Crossover Channel site represented the transitional zone between inner and outer harbor environments. Species which occurred only in the inner harbor, and others occurring only in the outer harbor inhabited the substrate at this site. These stations tended to switch back and forth between inner and outer harbor groups depending upon the season.

Distributions of the nuerically dominant species actually follow a series of overlapping ranges (Table 12) determined by salinity, sediment size, volatile solids, pollution, or any other gradients occurring along the length of the navigation channel.

Table 12. Highest percentage of benthic invertebrate community occupied by each species during the entire year, Grays Harbor, 1980-1981.

Organism	UPRIVER (EAST) ←				SITE		→ (WEST) TO OCEAN		
	C	CP	M	MC	MI	X	WF	DD	SJ[1]
CRUSTACEA									
Corophium spinicorne	91	43	8	16	12	36	0	0	0
Balanus sp.	8	73	52	0	0	5	0	0	87
Gnorimosphaeroma luteum	5	44	0	0	0	0	0	0	0
Eogammarus confervicolus	0	43	0	0	0	0	0	0	0
Leucon 1, unid.	0	42	9	53	9	0	0	0	0
Corophium brevis	0	20	0	0	85	0	0	0	0
Corophium salmonis	0	0	20	35	49	0	0	0	0
Cumella 1, unid.	0	0	0	0	15	0	0	0	0
Paraphoxus milleri	0	0	0	0	0	23	24	9	0
Eogammarus, all sp.	0	0	0	0	0	18	0	0	0
Corophium 1, unid.	0	0	0	0	0	14	0	0	0
Lamprops, Hemilamprops, or Mesolamprops sp.	0	0	0	0	0	10	0	0	0
Archaeomysis grebnitzkii	0	0	0	0	0	6	20	10	0
Eohaustorius sp.	0	0	0	0	0	0	14	0	0
Mandibuloluphoxus gilesi	0	0	0	0	0	0	10	0	0
Paraphoxus spinosus	0	0	0	0	0	0	0	0	27
Parapleustes (pugettensis?)	0	0	0	0	0	0	0	0	15
Ischyroceridae, all sp.	0	0	0	0	0	0	0	0	13
Caprella, all sp.	0	0	0	0	0	0	0	0	10
Diastylopsis 1, unid.	0	0	0	0	0	0	0	0	7
ANNELIDA									
Oligochaeta	97	72	12	31	45	21	0	0	0
Manayunkia aestuarina	83	87	89	81	31	0	0	0	0
Polydora hamata	47	0	0	0	0	0	0	0	0
Polydora ligni	0	76	0	0	45	27	0	0	0
Streblospio benedicti	0	58	23	58	57	11	0	0	0
Hobsonia florida	0	12	43	0	0	0	0	0	0
Polydora kempi japonica	0	0	0	9	0	0	0	0	0

Table 12. (continued)

Organism	C	CP	M	MC	MI	X	WF	DD	SJ
	UPRIVER (EAST)←				SITE		→(WEST) TO OCEAN		
ANNELIDA (continued)									
Pygospio elegans	0	0	0	0	74	0	0	0	0
Heteromastus filiformis	0	0	0	0	49	0	0	0	0
Glycinde armigera	0	0	0	0	43	0	0	0	0
Eteone longa	0	0	0	0	17	0	0	0	0
Glycinde picta	0	0	0	0	15	38	0	0	0
Armandia brevis	0	0	0	0	0	22	0	0	14
Nephtys longosetosa	0	0	0	0	0	20	6	0	0
Scolelepis squamata	0	0	0	0	0	20	0	0	0
Nephtys sp.	0	0	0	0	0	18	0	0	0
Chaetozone spinosa?	0	0	0	0	0	11	0	0	0
Paraonidae	0	0	0	0	0	6	0	0	0
Mediomastus sp.	0	0	0	0	0	0	65	0	0
Magelona sacculata	0	0	0	0	0	0	53	66	0
Ophelia limacina	0	0	0	0	0	0	41	35	0
Spio, all sp.	0	0	0	0	0	0	35	0	0
Scoloplos armiger	0	0	0	0	0	0	15	4	0
Hesionidae	0	0	0	0	0	0	10	0	0
Glycera capitata	0	0	0	0	0	0	0	13	0
Hemipodus borealis	0	0	0	0	0	0	0	9	0
Hesionidae 1, unid.	0	0	0	0	0	0	0	9	0
Syllidae, all sp.	0	0	0	0	0	0	0	0	22
Capitella sp.	0	0	0	0	0	0	0	0	13
Phyllodoce maculata	0	0	0	0	0	0	0	0	13
Eulalia 1, unid.	0	0	0	0	0	0	0	0	10
Paleanotus bellis	0	0	0	0	0	0	0	0	5
Lumbrineridae, all sp.	0	0	0	0	0	0	0	0	4
MOLLUSCA									
Macoma balthica	0	17	19	22	50	0	0	0	0
Mya arenaria	0	0	0	0	30	0	0	0	0
Macoma sp.	0	0	0	0	0	84	0	0	0

Table 12. (continued)

	UPRIVER (EAST) ←				SITE		→ (WEST) TO OCEAN		
Organism	C	CP	M	MC	MI	X	WF	DD	SJ
MOLLUSCA (continued)									
Siliqua (patula?)	0	0	0	0	0	0	9	0	0
Cryptomya californica	0	0	0	0	0	0	7	0	0
Tellina nuculoides	0	0	0	0	0	0	6	4	0
OTHER									
Nemertea	0	0	0	0	0	5	0	38	9
Nematoda	0	0	0	0	0	0	6	0	0
Dendraster excentricus	0	0	0	0	0	0	5	15	0
Pycnogonida, all sp.	0	0	0	0	0	0	0	0	3

[1] Percents are from the data set which excludes barnacles, except for value.

CONCLUSIONS AND RECOMMENDATIONS

The current maintenance dredging program appears to cause slightly depressed levels of abundance and biomass. However, there are several reasons why such an interpretation should be viewed with caution:

1. It was not known if the location sampled was directly affected by dredging. The highest observed biomass occurred during winter at the channel-bottom station of the Crossover Channel. Included in the sample was a 72 g cockle (Clinocardium nuttallii), which was 2 to 3 years old. This sample may have been taken from a location left undisturbed for several years.
2. If one excludes abundance and biomass data for obvious epifaunal species (e.g., crabs, shrimps, and barnacles) the resulting lower biomass and abundance values at South Jetty site obscure any trends regarding impacts associated with maintenance dredging, and subsequent disposal of dredged materials.
3. Channel-bottom invertebrate communities are irregularly distributed (Albright and Rammer, 1976). The widely variable values for abundance and biomass tend to mask changes in these parameters caused by dredging.
4. Dredging activity had no discernable effect on either biomass or abundance of invertebrates in those reaches subject to maintenance dredging during 1980 (Figure 60).

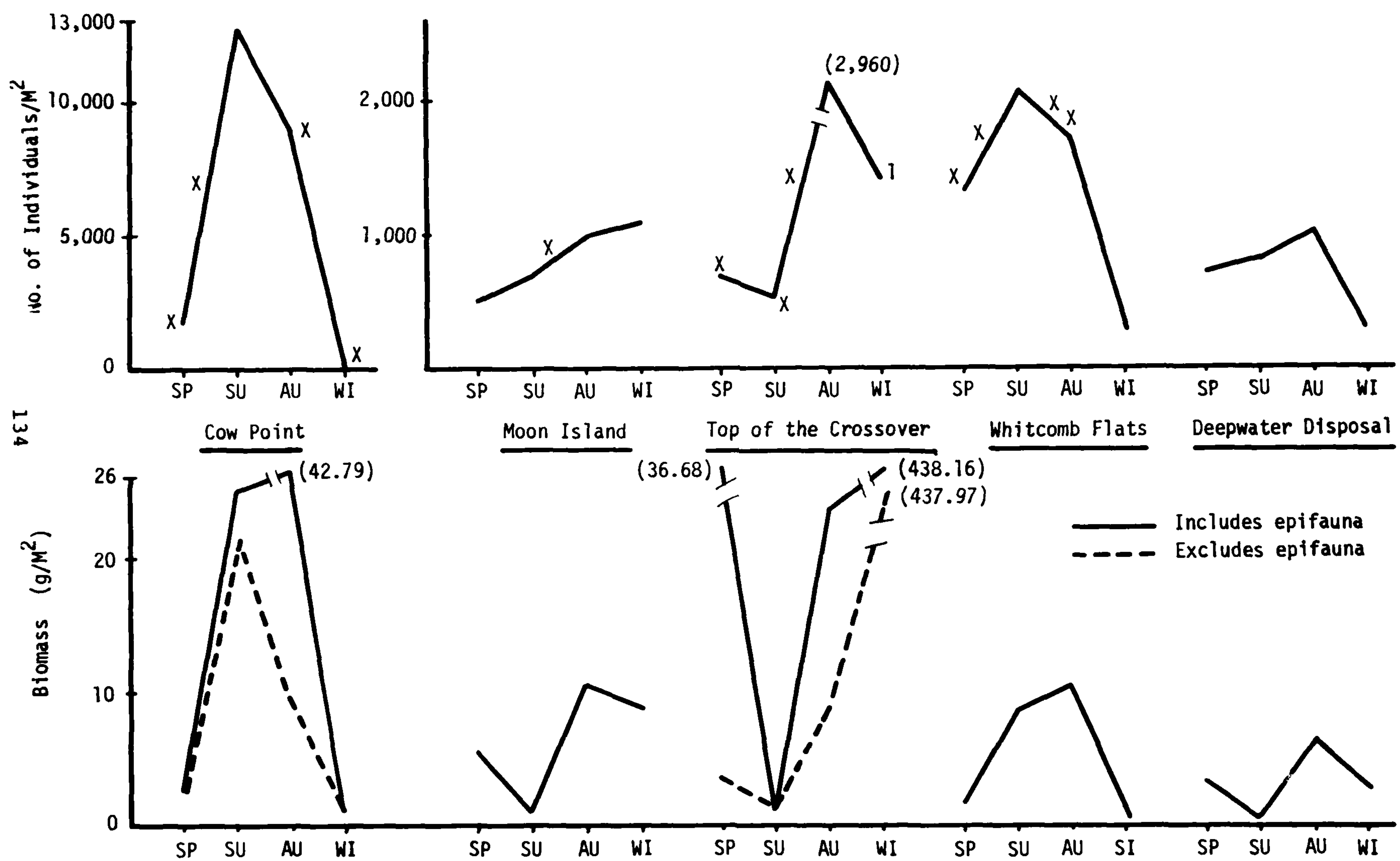


Figure 60. Abundance and biomass in relation to dredging activity (X), with disposal of dredged material at the Deepwater Disposal area, for channel-bottom stations, by season, Grays Harbor, Washington, 1980-81.

*Partial data missing. I without unid "worms".

5. No conclusions can be drawn from comparisons of the channel-side versus channel-bottom stations. Not only do these areas represent different habitats, but the extent of disturbances other than dredging to the channel-side (from sloughing, propwash, or natural sediment movement) are unknown. The substrate at Cow Point Channel Side Station (CP-S) underwent drastic changes between sample periods. Invertebrate populations exhibited large fluctuations in biomass at this station. Substrate at Cosmopolis Channel Side Station (C-S) was physically stable over time. The consistently high abundances and biomass at this station may reflect importance of stability to the benthic community.

Impacts of Channel Widening and Deepening

Loehr and Collias (1981) conclude that the proposed widening and deepening of the navigation channel will have no significant impact upon water charactertistics. Density and salinity stratification, natural phenomena in estuaries, will be accentuated in the inner harbor by the proposed dredging project. (Loehr and Collias, 1981).

We expect the majority of the fauna living on the channel bottom and side will be adversely affected by an activity of the magnitude of the deepening and widening project. However, no organisms present will be killed. Surviving invertebrates would provide a source of juveniles for recolonization of the newly exposed sediments. Recolonization would also be aided by immigration from intertidal and subtidal areas adjacent to the navigation channel. Since dredging could not be performed simultaneously throughout the navigation channel, those areas not yet dredged would contribute juveniles and mobile adults for recolonization of recently dredged areas.

A key factor determining the extent of impact from a physical disturbance such as dredging is the length of time required for recolonization. Swartz et al. (1980) found that recovery from dredging of a previously pristine area in Yaquina Bay took nearly a year. McCauley et al. (1977) found that the benthic community in Coos Bay took only 28 days to recover from maintenance dredging activity. The authors in the latter study concluded that frequent disturbances in the Coos Bay navigation channel (such as maintenance dredging and propwash) had resulted in a channel fauna adapted to unstable habitat conditions.

McCall (1977) concluded that communities in shallow, soft-bottom sediments exhibit patchy distributions due largely to localized physical disturbances. Once an area was disturbed (partially or completely defaunated), certain "opportunistic" species were found to be highly proficient at colonizing the site. Such opportunistic species were found to have particular life history traits which greatly facilitated their ability to colonize disturbed areas. In estuaries where maintenance dredging and other activities associated with shipping, such as propwash, continually disturb the sediments, the benthos will probably be comprised largely of opportunistic species, which could readily explcit newly created habitat. Cliver et al. (1977) found that recovery time of the benthos in Monterey Bay from the impacts of dredged material disposal was directly related to the degree of natural stress (or disturbance) the site was subjected to before disposal of dredged material. Thus, the prior history of disturbance is important in determining the rate of recovery of the benthic community. Oliver et al. (1980) found that larvel polychaetes and mobile crustaceans were the primary colonizers of disturbed sites in Monterey Bay and Moss Landing.

Grays Harbor presents a situation similar to that in Coos Bay. The fauna in the navigation channel is subjected to frequent disturbance/stress. In inner Grays Harbor, maintenance dredging, shipping activity, pollution, large-scale sediment movement, and fluctuations in salinity are some of the disturbances with which the fauna must cope. In outer Grays Harbor, wave action, dredging, and shipping activities cause frequent disturbances to the fauna.

Several of the species which dominate the channel fauna in Grays Harbor are opportunistic species (Table 14). In addition, other species, such as Paraphoxus milleri are closely related to other opportunistic species which may mean that they are also

Table 13. Grays Harbor benthic species described in literature as being opportunistic.

Species	Literature
Corophium spp.	Albright & Rammer, 1976; Swartz et al., 1980
Streblospio benedicti	McCall, 1977; Williamson et al., 1977
Armandia brevis	Oliver et al., 1977; Swartz et al., 1980
Ophelia limacina	Williamson et al., 1977
Polydora kempi	Williamson et al., 1977
Polydora ligni	Williamson et al., 1977
Macoma balthica	Swartz et al., 1980
Parapleustes pugettensis	Swartz et al., 1980

opportunistic species. Most, but not all, opportunistic species are small, tube-dwelling surface-deposit feeders, whose populations exhibit patchy distribution patterns in space and time. The communities in which they are abundant have an uncomplicated structure.

Most studies dealing with dredging effects have dealt primarily with acute impacts. Bella and Williamson (1980) have attempted to provide a "diagnosis" for identifying potential chronic impacts. The encouragement of stratification which would result from deepening the navigation channel could lead to an increased rate of siltation in the channel. If this occurred, the result might be greater stress to channel-bottom fauna. However, this would probably not lead to major shifts in community structure because existing invertebrate community is highly adapted to a stressful environment.

Loss of intertidal habitat represents a potentially far more serious impact to the benthic community than the actual deepening of the current channel bottom. A total of 2 acres of intertidal habitat will be changed to shallow subtidal habitat. This will occur across the channel from the Cow Point Site at the eastern tip of Rennie Island.

Comparisons between abundance and biomass at intertidal versus subtidal sample locations was hampered by the use of different sampling gear and techniques. Greater abundance and biomass at intertidal sites is partially explained by the increased efficienty of intertidal sampling methods. However, it does not seem reasonable that such large differences are due entirely to different sampling methods. Thus, it appears likely that a net reduction in both biomass and abundance will result in the navigation improvement project. The intertidal environment at Cow Point is fairly stable. The channel bottom exhibited substantial environmental fluctuations between sampling periods, indicating a dynamic, less stable situation. Dredging would likely cause a net reduction of numbers of Corphium spinicorne. The loss of this important food organism would affect its predators.

The proposed widening of the navigation channel would also probably encroach upon intertidal areas between Cow Point and a point immediately west of the tip of Moon Island. Along this reach, the intertidal area drops off directly into the navigation channel. Permanent loss of intertidal habitat would probably cause a significant loss of abundance and biomass of invertebrate organisms. The largest portion of the loss in biomass would be caused by loss of habitat for soft-shell clams. The quantity of intertidal habitat that could be lost along this reach is unknown.

West of Moon Island, widening the navigation channel would result in loss of shallow subtidal habitat adjacent to the navigation channel. The impact of this loss is unknown. However, scarcity of clams in the navigation channel west of the Crossover Channel Site may indicate that there would be a significant drop in overall biomass caused by loss of this shallow subtidal habitat. This possibility is supported by qualitative sampling in the lower intertidal area at Whitcomb Flats, where moderate numbers of cockles were found (Albright and Hammer, 1976). Other clams which could be expected to occur in these shallow subtidal areas are horse clams (<u>Tresus</u> spp.) and bent-nose clams (<u>Macoma nasuta</u>).

Impacts of dredging could be partially mitigated through proper timing of dredging activity. While biomass of invertebrates was often low during the summer, abundance was often high. This was due to the large numbers of juveniles in the population. Dredging during late winter and early spring, before the appearance of juveniles which could recolonize the newly exposed sediments, might minimize recovery time of the benthos. However, many of the opportunistic species (e.g., <u>Corophium</u> spp., <u>Streblospio benedicti</u>, *Macoma balthica*) inhabiting the navigation channel breed several times per year. Thus, the timing of dredging is less critical than if a pristine area were being dredged.

The Marsh Establishment Site has been named as a possible location for the creation of a saltmarsh using dredged materials. The project if constructed would affect an estimated 16 hectares of intertidal area.

Site M had relatively high numbers of individuals and biomass. Most of the disposal for marsh creation would occur in the upper and mid-intertidal region. A previous study on the impact of dredged material disposal on intertidal benthos in Grays Harbor indicates that the majority of benthic invertebrates would be lost to initial disposal at the marsh creation site (Albright and Rammer, 1976). Key species eliminated would include *Corophium salmonis*, *Manayunkia aestuarina*, and *Macoma balthica*.

The loss of invertebrates would be mitigated by recolonization over much of the marsh establishment area, especially by *Manayunkia*, which prefer higher elevation sites. In addition, increased primary productivity, once the marsh plants become established, may increase secondary production in the adjacent benthic habitats.

New configuration of the intertidal area at Site M resulting from dredged material disposal may affect adjacent intertidal areas through alteration of current flow patterns. As discussed by Bella and Williamson (1980), reduced current flows could likely cause a reduced flushing rate and rate of sediment turnover (RST), thus causing an increase in the organic content of sediments (OCS). Possible results of such changes might include an increase in hydrogen sulfide in the sediments and an increase of free sulfides in the water. Such impacts would adversely impact benthic populations. According to Bella and Williamson (1980), such changes would result from the shift out of an equilibrium state of the OCS-RST plane.

The Marsh Control site will remain unchanged by the proposed dredging activities.

Comments on impacts to various reaches will be discussed in greater detail by navigation channel reach. (Fig. 61):

1. Cosmopolis

To comment on possible impacts to organisms and habitat within the South Aberdeen Reach and South Aberdeen Turning Basin proposed dredging areas, Cosmopolis site data will be used.

Slightly more than 16 hectares of additional habitat will be disturbed in South Aberdeen Reach. This is a 67% increase in amount of disturbed bottom in this reach (Opdycke, personal communication, 1981[1]). The newly exposed substrate is expected to be composed of more sand and less mud (i.e., silts and clays), (Coburn, personal communication, 1981[2]). It is

[1] USFWS Ecological Services, Olympia, Washington 98502.

[2] CCE Seattle District, Seattle, Washington.

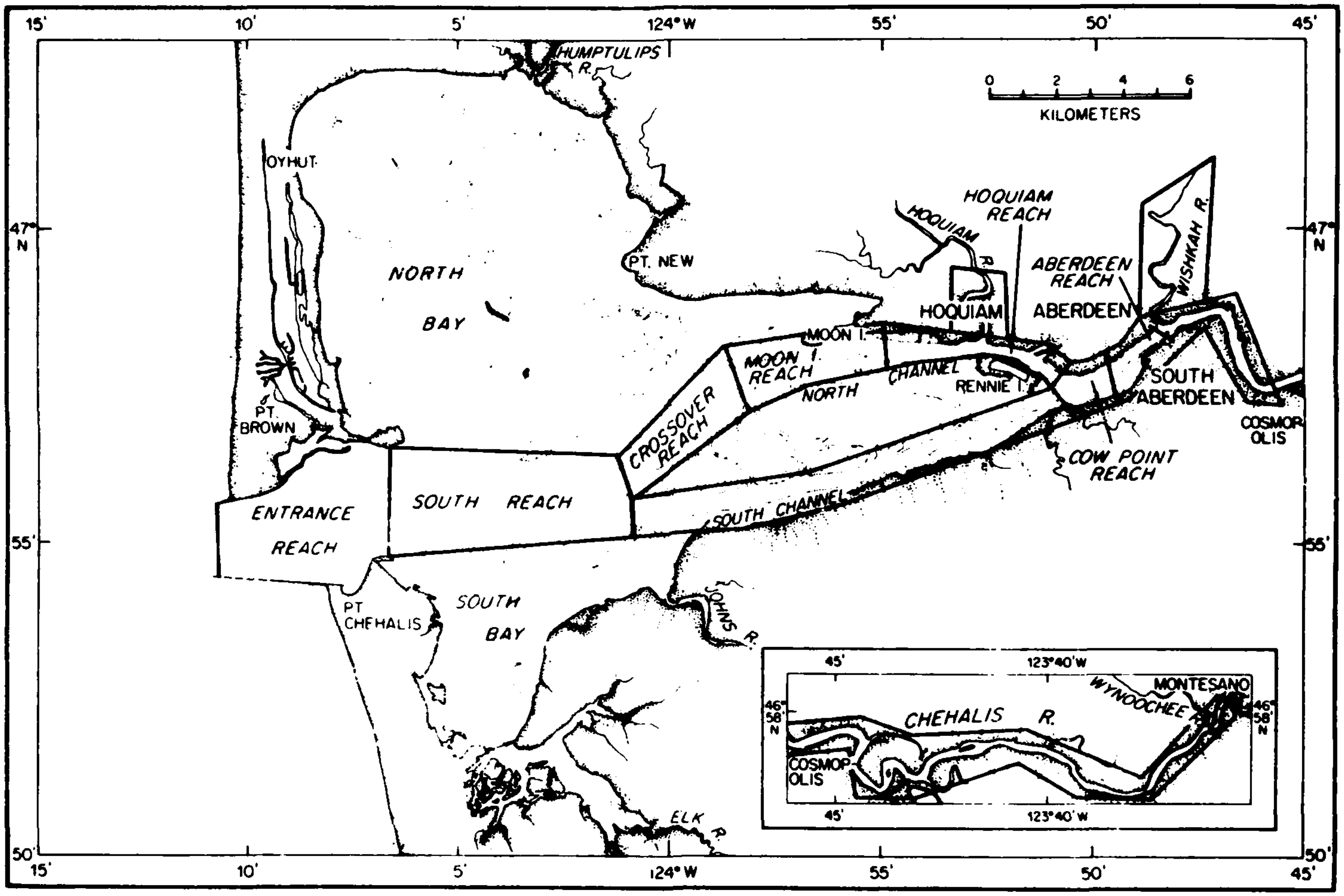


Figure 61. Subdivisions of Grays Harbor

expected that organic content of the newly-exposed sediments will be lower at least initially. Salinity will be basically the same.

Species diversity, abundance and biomass are expected to be lower immediately after dredging. *Corophium spinicorne*, an opportunistic species is expected to recolonize the newly exposed bottom. *Corophium* feeds by processing water for its detritus content, and is particularly abundant in estuaries where salinity is reduced and silting is heavy (Kozloff, 1973). Since the Chehalis River upstream of the South Aberdeen Reach will not be dredged, it is expected that deposition, of sediments, by the river will remain about the same.

Other invertebrates found in Cosmopolis subtidal invertebrate assemblages that are expected to recolonize are: oligochaetes, *Polydora hamata* and the polychaete *Nereis limnicola*.

2. Cow Point

Dredging in the Aberdeen and Cow Point Reaches, the Cow Point Turning Basin, and the eastern 3/5ths of the Hoquiam Reach combined affect the greatest amount of undisturbed subtidal acreage in the estuary. Slightly more than one hectare (2 acres) of intertidal habitat will be lost from the south side of the channel. The actual areas presently disturbed and those proposed to be disturbed by reach (Alan Coburn, CE, Personal comm.) are:

1. Aberdeen Reach: 16.19 ha present - 18.21 ha proposed,
2. Cow Point Reach: 12.13 ha present - 2.02 ha proposed,

3) Cow Point Turning Basin; 3.24 ha present - 3.24 ha proposed, and

4) Hoquiam Reach - east 3/5-th's; 37.64 ha present - 1.21 ha proposed.

Salinity will stay within the present range, stratification would be accentuated during mean river flow. Thus, exposure time to extremes of low and high salinity could be longer than at present. More sand and less clay and silt is expected on newly-exposed bottoms at inner harbor reaches west and Crossover Reach.

Because the spionid Polydora ligni thrives where sediments are overturned frequently and where sawdust and wood debris abound (McCauley et al., 1976), populations will probably decline after completion of the project until wood debris again becomes a major component of the substrate. The wood fraction is assumed to be from log-export activity nearby. Past practices of allowing wood debris to go into the river is no longer permitted, however.

Streblospio benedicti might initially recolonize these reaches along with Corophium and oligochaetes. S. benedicti was an important opportunist and recolonizer in a Long Island Sound infaunal study (McCall, 1977). McCauley et al. (1976) concluded that S. benedicti is well adapted to estuarine sediments that are subject to frequent change either from continual disturbance by currents or harbor activity or from continual deposition of overlying sediment.

3. Moon Island

Dredging the eastern 4/5-th's of the Moon Island Reach and the western 2/5-th's of the Hoquiam Reach will destroy some intertidal habitat. 40.47 hectares in the eastern portion of the Moon Island Reach is dredged now. The proposed project would add an additional 12.95 hectares after deepening and widening. Twenty-five hectares are currently dredged in the western portion of Hoquiam Reach. An additional .81 hectares would be added after deepening and widening. There will be a loss of some intertidal habitat in the western half of this reach. The channel bottom is proposed to be 15.25 meters wider here. Because of the wide, gently sloping intertidal region in this area and its' close proximity to the current channel side, some sloughing is expected. Populations of Glycinde spp. are expected to decline after dredging and be replaced by Corophium spp.

4. Top of the Crossover Channel

Twenty-three percent more bottom area is expected to be disturbed in Crossover Reach after deepening and widening (a total of 75 hectares). Three additional hectares in Moon Island Reach will be disturbed after deepening and widening (a 32% increase). The total area disturbed along this stretch of the channel would increase from 71 hectares to 78 hectares if widening and deepening occurs.

The polychaete _Armandia brevis_ is an opportunist already present at this site. This organism showed dramatic larval recruitment after the final dredging at a Yaquina Bay site (Swartz, R.C. et al., 1980). Since _Armandia_ appears to thrive despite maintenance dredging in Grays Harbor, populations should recover quickly after dredging.

5. Whitcomb Flats

The Whitcomb Flats site will be used to address possible impacts to the South Reach. A total of 83 hectares of subtidal habitat would be disturbed by this project. This total does not include areas near Whitcomb Flats where sloughing of the shallow-subtidal area between MLLW and the top of the present channel-side may occur.

After widening and deepening, ocean-derived sands are expected to constitute the new bottom and recolonization is expected to occur from surrounding undredged habitat. Impacts to crustacean populations should be minimal. Impacts to annelids and clams are expected to be more pronounced. _Magelona_ appears to do well where the substrate is disturbed by either natural or man-made phenomena. Populations of immobile species like _Siliqua_ and _Dendraster_ will be drastically reduced by the project. Populations of these species will take much longer to recover as they are species requiring a stable environment. Maintenance dredging activities in this reach may preclude recovery of these organisms.

6. Deepwater Disposal Site

At the Deepwater Disposal Area the present benthos was disturbed by dredged material disposal throughout the study. Abundance and biomass was consistently lower than most other subtidal stations.

With the proposed dredging, increased amounts of dredged material would be disposed of here. This will probably lower still further, abundance and biomass of benthic invertebrates. Also affected would be some amount of benthos in the path of bottom sediment moving from the disposal area towards Damon Point and North Bay.

Species expected to recolonize with least difficulty are *Magelona sacculata*, *Ophelia limacina*, nemerteans, *Archaeomysis grebnitzkii* and *Paraphoxus milleri*.

7. South Jetty - Entrance Reach

The Entrance Reach will not require maintenance dredging. However, the South Jetty site might be used for dredged material disposal (Ron Thom, personal communication[1]). If this is done, a benthic fauna similar to that of the Deepwater Disposal site will probably develop.

[1] ACOE Seattle District, Seattle, Washington.

Covering the cobble, shell and gravel substrate at this site would eliminate the barnacle population. Many organisms associated with these barnacles (such as amphipods and polychaetes) would also be destroyed. In addition, covering the cobble, gravel and old clam shells would reduce the biological importance of this site by eliminating much of the epifauna dependent upon this substrate (e.g., juvenile rock crabs, caprellid amphipods, mussels, nudibranchs, pycnogonids, chitons, etc.). *Paraphoxus*, a sand burrower (Smith and Carlton, 1975), and the opportunistic polychaete *Ophelia limacina* are expected to be key species in recolonization.

Summary

Subtidal and intertidal sites will be largely defaunated if directly disturbed by dredging or disposal. Other subtidal and intertidal areas will be affected primarily by sloughing of substrate into the channel. Total defaunation will occur at the proposed Marsh Establishment site if the marsh establishment project is constructed.

We believe natural disturbances (waves, wind, tides, etc.) are greater than disturbances caused by dredging and disposal at stations not directly affected by widening and deepening.

Whether an organism will be able to recolonize depends mainly upon it's life cycle, it's mobility throughout the life cycle, and it's reproductive capacity. The more resiliant opportunistic organisms such as Corophium, Streblospio, Armandia, Ophelia, Paraphoxus, etc. are expected to recolonize disturbed areas quickly.

Recommendation

Mitigation of impacts to the benthos may be achieved by dredging in late winter or early spring: February thru April. This is based on the conclusion that large numbers of juveniles entering the system in spring would lead to quick colonization of exposed sediments.

RECOMMENDATIONS FOR FURTHER STUDY

1. Some studies after the proposed deepening and widneing project is completed should be done to study recolonization. Little information about recovery of or secondary impacts on benthic invertebrate populations is available.
2. If dredging is to take longer than one year, observations of the benthos should be made once-a-year in late spring at the sites sampled in this study. This would provide information numbers of mature adults available to "seed" dredged areas for recolonization and cumulative dredging effects.
3. The possibility of using an alternative grab sampler for subtidal sampling should be investigated.
4. If the South Jetty site is used as a disposal area, a closer look should be taken at clam populations present (e.g., *Tresus* sp.) and the epifaunal organisms which appear to contribute a large amount of biomass to the invertebrate community at this site.
5. We also recommend sampling (lower-intertidal) locations with both subtidal and intertidal collection methods to compare efficiencies. At least one soft-bottom and one hard-bottom site should be sampled. This will give much more meaning to comparisons of intertidal vs. subtidal information.

LITERATURE CITED

Albright and Rammer. 1976. The effect of intertidal dredged material disposal on benthic invertebrates in Grays Harbor, Washington. Work performed under Washington Department of Ecology Contract No. 74-164. Maintenance Dredging and the Environment of Grays Harbor Washington; Appendix E: Invertebrates. U.S.A.C.E., Seattle, WA. 244 pp.

Bella, D.A. and K. J. Williamson. 1977. The diagnosis of chronic impacts of estuarine dredging. Chapter VII, Section B; In Environmental Impacts of Dredging in Estuaries. Schools of Engineering and Oceanography, Oregon State University, Corvallis, Oregon 629-666 pp.

Belle, D.A. and K.J. Williamson. 1980. Diagnosis of chronic impacts of estuarine dredging. J. Environmental Systems, 9(4):289-311.

Bray, J. and J. Curtis. 1957. An ordination of the upland forest communities of southern Wisconson. Ecolo. Monogr. 27(4):325-249

Gatto, L.W. 1978. Estuarine processes and intertidal habitats in Grays Harbor, Washington. A demonstration of remote sensing techniques. U.S. Cold Regions Research and Engineering Laboratory, Springfield, VA. CRREL Report 78-18. 79 p.

Hancock, D.R., J.E. McCauley, J.M. Stander, and P.T.Tester. 1977. Distribution of benthic infauna in Coos Bay. Chapter VI; In Environmental Impacts of Dredging in Estuaries. Schools of Engineering and Oceanography, Oregon State University, Corvallis, Oregon. 509-579 pp.

Hoffman, E.G., D. C. Fagergren, and S.H. Olsen. 1980. Grays Harbor Toxicity Evaluation Study - Phase II. ITT Rayonier, Inc., Olympia Research Division, Shelton, WA. 56 pp.

Holton, R.L. et al. 1980. Annual Report #1 Columbia River Estuary Data Development Program 1 Oct. 1979 - 30 Sept. 1980. For the Pacific Northwest River Basins Commission, Vancouver, WA, and additional unpublished data.

Kozloff, E.N. 1973. Seashore Life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago. University of Washington Press, Seattle and London. 282 pp.

Krebs, C.J. 1972. Ecology: The Experimental Analysis of Distribution and Abundance. Harper and Row Publishers, Inc., New York. 694 pp.

Loehr, L.C. and E.E. Collias. 1981. A Review of Water Characteristics of Grays Harbor 1938-1979 and an Evaluation of Possible Effects of the Widening and Deepening Project upon Present Water Characteristics. Grays Harbor and Chehalis River Improvements to Navigation Environmental Studies. Seattle District U.S. Army Corps of Engineers, Seattle. 97 pp.

McCall, P.L. 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. Journal of Marine Research 35(2). pp. 221-266.

McCauley, et al. 1976. Maintenance dredging and four polychaete worms. Proceeding of the Speciality Conference on dredging and its environmental effects. Mobile, Alabama 26-28 January 1976. American Society of Civil Engineers. pp. 673-683

McCauley, J.E., R.A. Parr, and D.R. Hancock. 1977. Benthic infauna and maintenance dredging: A case study. Water Research 11(2): pp. 233-242.

Nichols, F.H. 1979. Natural and anthropogenic influences on benthic community structure in San Francisco Bay: In San Francisco Bay: The Urbanized Estuary. T.J. Conomos, Editor, pp. 409-426.

Oliver, J.S., P.N. Slattery, L.W. Hulberg, and J.W. Nybakken. 1977. Patterns of succession in benthic infaunal communities following dredging and dredged material disposal in Monterey Bay. Tech. Rpt. D-77-27, U.S. Army Engineer Dredged Material Research Program. Vicksburg, MS. 186 pp.

Phipps, J.P. and K.D. Schermer. 1980. Analysis of sediments at invertebrate study sites. Grays Harbor Navigation Improvement Study. Seattle District U.S. Army Corps of Engineers, Seattle, 10 pp.

Proctor, C.M., J.C. Garcia, D.V. Galvin, M.B. Bailey, and G.W. Brown Jr. 1980. An ecological characterization of the Pacific northwest coastal region. 5 vol. U.S. Fish and Wildlife Service, Biological Services Program. FWS/OBS-79/11 through 79/15.

Smith and Carlton, editors. 1975. Light's Manual: Intertidal Invertebrates of the Central California Coast. Third edition. University of California Press, Berkeley. 716 pp.

Swartz, R.C., W.A. DeBen, F.A. Cole, and L.C. Bentsen. 1980. Recovery of the macrobenthos at a dredge site in Yaquina Bay, Oregon. Chapter 20; In Contaminants and Sediments, Volume 2. pp. 391-408.

Thom, R.M., J.W. Armstrong, C.P. Staude, and K.K. Chew. 1977. Impact of sewage on benthic marine flora of the Seattle area: Preliminary results. pp. 200-220, In: The Use, Study and Management of Puget Sound. Washington Sea Grant Publ. WSG-WO 77-1.

Williamson, K.J., D.A. Bella, D.R. Hancock, J.M. Stander, C.K. Sollit, R.T. Hudspeth, J.E. McCauley, and L.S. Slotta. 1977. Conclusions. Chapter VIII; In Environmental Impacts of Dredging in Estuaries. Schools of Engineering and Oceanography, Oregon State University, Corvallis, Oregon. 667-675 pp.

Williamson, K.J., D.A. Bella, and H.R. Hancock. 1977. Sediment characteristics at the ten Coos Bay stations. Chapter VII, Section A; In Environmental Impacts of Dredging in Estuaries. Schools of Engineering and Oceanography, Oregon State University Corvallis, Oregon. 581-628 pp.

REFERENCES USED FOR INVERTEBRATE IDENTIFICATION

Banse, K. 1979. Ampharetidae (Polychaeta) from British Columbia and Washington. Canadian J. of Zool. 57(8):1543-1552.

Banse, K. and K. D. Hobson. 1974. Benthic errantiate polychaetes of British Columbia and Washington. Fisheries and Marine Service Bull. 185. Ottawa. 111 p.

Barnard, J. L. 1973. Revision of Corophiidae and Related Families (Amphipoda). Smithsonian Institution Press. Smithsonian Contributions to Zoology Number 151. 27 pp.

Barnard, J. L. 1969. The families and genera of marine Gammaridean Amphipoda. U.S. Nat. Museum Bull. No. 271. Smithsonian Institution Press, Washington. 535 p.

Brinkhurst, R. O. 1963. Taxodomical studies on the Tubificidae (Annelida, Oligochaeta) Internationale ReveedenGesamten Hydrobiologie. Akademie-Verlag, Berlin. Pages 7-13.

Brinkhurst, R.O. 1971. A guide for the identification of British Aquatic Oligochaeta. Scientific Publ. No. 22. Freshwater Biological Assoc.

Bousfield, E. L. 1979. The Amphipod superfamily Gammaroidea in the northeastern Pacific region: systemics and distributional ecology. Bull. Biol. Soc. Wash. 3:297-357.

Butler, T. H. 1980. Shrimps of the Pacific coast of Canada. Dept. of Fisheries and Oceans Bull. No. 202. Ottawa, Canada. 280 pp.

Calman, W. T. 1912. The Crustacea of the order Cumacea in the collection of the United States National Museum. U.S. Nat. Mus., Proc. 41:603-676.

Coan, E. V. 1971. The northwest American Tellinidae. The Veliger 14(supp) 63 p.

Cornwall, I. E. 1975. The Barnacles of British Columbia. British Columbia Provincial Museum, Department of Recreation and Conservation, Handbook No. 7. 69 p.

Dunnill, R. M. and D. V. Ellis. 1969. Recent species of the genus Macoma (Pelecypoda) in British Columbia. National Museum of Canada, Natural Papers No. 45:1-34.

Dunnill, R. M. And E. V. Coan. 1968. A new species of the genus Macoma (Pelecypoda) from West American coastal waters, with comments on Macoma calcarea (Gmelin 1791). Natural History Paper No. 43. National Museum of Canada. 19 p.

Eriksen, C. H. Aspects of the limno-ecology of Corophium spinicorne Stimpson (Amphipoda) and Gnorimosphaeroma oregonensis (Dana) (Isopoda). Crustaceana 14:1-11.

Hartman, O. 1968. Atlas of the Errantiate Polychaetous Annelids from California, Allan Hancock Foundation, Univ. of Southern Calif. Los Angeles. 828 p.

Hartman, O. 1969. Atlas of the sedentariate polychaetous annelids from California Allen Hancock Foundation. Univ. of Southern Calif., Los Angeles. 812 p.

Henry, D. P. 1940. The Cirripedia of Puget Sound with a key to species. Univ. of Wash. Publ. in Oceanography 4(1):1-48.

Henry, D.P. 1942. Studies on the sessile Cirripedia of the Pacific coast of North America. Univ. of Wash. Publ. in Oceanography 4(3):95-134.

Hertlein, L. G. 1961. A new species of Siliqua (Pelecypoda) from western North America. Bull. S. Calif. Acad. of Sci. 60(1):12-19.

Hobson, K. D. and K. Banse. 1980 draft. Sedontiate and archiannelid polychaetes of British Columbia and Washington.

Hoestlandt. H. 1973. Etude systematique et genetique detrois especes Pacifigues Nord. Americaines du genre Gnorimosphaeroma menzies (Isopodes Flabellifores) I. considerations generales et systematique.

Kozloff, E. N. 1974. Keys to the marine invertebrates of Puget Sound, the San Juan Archipelago, and adjacent regions, Univ. of Wash. Press, Seattle, WA. 226 p.

Kozloff, E.N. 1976. Seashore life of Puget Sound, the Strait of Georgia and the San Juan Archipelago, Univ. of Wash. Press, Seattle, Wash. 282 p.

Lie, U. 1969. Cumacea from Puget Sound and off the northwestern coast of Washington, with descriptions of two new species. Crustaceana, 17:19-30.

Lie, U. 1971. Additional Cumacea from Washington, U.S.A., with description of a new species. Crustacean 21:33-36.

Keen, A. M. and E. Coan. 1974. Marine molluscan genera of western North America an illustrated key. Stanford Univ. Press. Stanford, CA 208 pp.

Light, W. T. 1969. Extension of range for Manayunkia aestuarina (Polychaeta:Sabellidae) to British Columbia. J. Fish. Research Board of Canada 26(11)3088-3091.

Menzies, R. J. 1954. A review of the systematics and ecology of the genus Exosphaeroma with the description of a new genus, a new species, and a new subspecies (Crustacea, Isopoda, sphaeromidae). Amer. Museum of Natural History. New York, Number 1683:1-24.

Needham, J. G. and P. R. Needham. 1975. A guide to the study of fresh-water biology. Holden-Day Inc. San Francisco. 108 p.

Otte, G. 1975. A laboratory key for the identification of Corophium species (Amphipoda, Corophiidae) of British Columbia. Tech. Report No. 519. Research and Development Direct . Vancouver, B.C., 19 p.

Riegel, J. A. 1959. Some aspects of osmoregulation in two species of Sphaeromid isopod crustacea. Biol. Bull. 116:272-284.

Riegel, J.A. 1959. A revision in the Sphaeromid genus Gnorimosphaeroma menzies (Crustacea: Isopoda) on the basis of morphological, physiological and ecological studies on two of its subspecies. Biol. Bull. 117:154-162.

Rudy, P., Jr., and L. H. Rudy. Oregon estuarine invertebrates an illustrated guide to the common and important invertebrate animals. Oregon Inst. Marine Biol. Charleston, Oregon, 131 p.

Sara, G. O. 1900. An account of the Crustacea of Norway, Vol. 111, Cumacea. The Bergen Museum, Bergen, Norway. 115 pp.

Schultuz, G. A. 1975. How to know the Marine Isopod Crustaceans. Wm. C. Brown Company Publishers, Dubuque, Iowa. 359 pp.

Shoemaker, C. R. 1949. The Amphipod genus Corophium on the West coast of America. J. Wash. Acad. Sci. 39(2):66-82.

Smith, R. I., and J. T. Carlton (eds.). 1975. Light's manual: intertidal invertebrates of the central California coast. Univ. of Calif. Press, Berkeley. 716 p.

Tegelberg, H. C. 1969. A new Pacific razor clam species, Siliqua. U.S. F. W. S. Bur. of Comm. Fisheries, Seattle, Wash. Cpuisu R. No. 69-4.

Ward, H. B., and G. C. Whipple. Edited by W. T. Edmondson. 1959. Fresh-water Biology: Second Edition. John Wiley & Sons, Inc., New York. 1248 pp.

APPENDIX A

Benthic Invertebrates Species

Collected in Grays Harbor, 1980 - 1981

Cnidaria

Unid sp.

Porifera

Unid. sp.

Platyhelminthes

Unid. spp.

Nemertea

Tetrastemma 1, unid.
Unid. sp.

Nematoda

Unid. spp.

Chaetognatha

Unid. sp.

Annelida

Oligochaetes

Abarenicola 1, unid.

Armandia brevis
Barantolla americana
Capitella capitata
Capitella dizonata
Unid. Capitellidae
Chaetozone spinosa
Chone ecaudata

Eteone longa
Eteone 1, unid.
Eulalia 1, unid.
Eulalia 2, unid.
Euzonus mucronata
Glycrea capitata
Glycera convoluta
Unid. Glyceridae
Glycinde armigera
Glycinde picta
Glycinde polygnatha
Goniadidae, Unid. sp.

Annelida (continued)

Hemipodus borealis
Hesionidae l, unid.
Heteromastas filformis
Hobsonia florida
Lumbrineridae, unid. sp
Lumbrineris zonata
Magelona sacculata
Malacoceros (fuliginosus?)
Malacoceros l, unid.
Manayunkia aestuarina
Mediomastus l, unid.
Nephtys caeca
Nephtys (californiensis?)
Nephtys longesetosa

Nereis limnicola
Nereis vexillosa
Nereis sp.
Ophelia limacina
Opheliidae, unid. sp.
Orbinia sp.
Orbiniidae, unid. sp.
Paloanotus bellis
Paleanatus occidentale
Paraonidae, unid. sp.
Pholoe minuta
Phyllodoce maculata
Phyllodoce l, unid.
Phyllodoce sp.
Polydora brachycephala
Polydora columbiana
Polydora hamata
Polydora kempi japonica
Polydora ligni
Polydora sp.
Polynoidae, unid. sp.
Pygospio elegans
Samytha californiensis?
Scolelepis squamata
Scolelepis l, unid.
Scoloplos acmeceps
Scoloplos armiger
Spio butleri
Spio filicornis
Spio sp.
Spionid M

Spionidae, unid. sp.
Spiophanes bombyx

Annelida (continued)

Streblospio benedicti
Syllidae 1, unid.
Syllidae, unid. sp.
Syllis 1, unid.
Thelenessa spinosa?
Unid sp.
Unid. sp. M

Mollusca
-Bivalves-

Cooperella sp.
Corbicula sp.
Clam sp.
Clinocardium ciliatum
Clinocardium nuttallii
Clinocardium sp.
Cryptomya californica
Macoma balthica
Macoma (inquinata)
Macoma nasuta
Macoma 1, unid.
Macoma sp.
Modiolus rectus
Mya arenaria
Mytellidae, unid. sp.
Mytilus edulis
Siliqua patula
Tellina nuculoides

Tellina 2, unid.

Tresus sp.

-Other mollusca-

Hanleya 1, unid.
Odostomia 1, unid.
Nudibranchia 1, unid.
Nudibranchia 2, unid.
Nudibranchia 3, unid.

Echinodermata

Dendraster excentricus

Arthropoda
-Crustacea-

Acanthomysis macropsis

Arthropoda (continued)
-Crustacea-

Ampithoe sp.
Ampithoe valida
Ampithoidae, unid. sp.
Ancinus (granulosus?)
Anisogammarus pugettensis
Archaeomysis grebnitzskii
Balanus crenatus
Balanus glandula
Balanus sp.
Calanoidea, unid. sp.
Callianassa californiensis
Cancer magister
Cancer productus
Caprella incisa
Caprella l, unid
Caprellidea, unid sp.
Caridea mysis
Clausidium vancouverensis
Corophium brevis
Corophium salmonis
Corophium spinicorne
Corophium sp.
Corophium l, unid.
Crangon franciscorum franciscorum
Crangon nigricauda
Crangonidae, unid. sp.
Cumacea, unid. sp.
Cumella l, unid.
Cyclopoida, unid. sp.
Cymadusa uncinata
Diastylis l, unid.
Diastylopsis l, unid.
Eogammarus confervicolus
Eogammarus oclairi
Eogammarus sp.
Eohausterius spp.

Gammaropsis or Megamphopus
Gnorimosphaerama luteum
Gnorimosphaerama oregonense
Harpacticoida (Scottolana canadensis)
Ischyroceridae l, unid.
Ischyroceridae sp.
Jassa l, unid.
Lamprops, Hemilamprops, or Mesolamprops
Leptochelia dubia

Leucon l, unid.

Arthropoda (continued)
-Crustacea-

Mandibulophoxus gilesi
Munna (stephenseni?)
Neomysis mercedis
Orchestia traskiana
Orchestia sp.
Orchestoidea sp.

Oxyurostylis 1, unid.
Pagurus 1, unid.
Paraphoxus milleri
Paraphoxus spinosus
Paraphoxus sp.
Parapleustes (*pugettensis*?)
Podocerus sp.
Saduria entomon
Synchelidium (*shoemakeri*?)
Tanais 1, unid.
Upogebia pugettensis

-Insecta-

Anurida maritima
Insect, unid. larva 1
Insect, unid. larva 2
Insect, unid. larva 4
Entomobrya 1, unid.
Insect larva M

-Chelicerata-
Achelia nudiuscula
Ammothella 1, unid.
Nymphon 1, unid.
Type 2, unid.
Pycnogonid sp.

Ectoprocta

Ectoprocta, unid. sp.
Entoprocta, unid. sp.

Pisces

Pholis ornata
Unid. fish embryo

Appendix B

Grain Size and Total Volatile Solids Analysis of Sedirents Collected in Grays Harbor, 1980.

Table 1. Results of grain size analysis of samples from all benthic sampling sites, Grays Harbor, 1980.

Site	Elevation	Gravel Spr	Gravel Sum	Coarse Sand Spr	Coarse Sand Sum	Fine Sand Spr	Fine Sand Sum	Silt Spr	Silt Sum	Clay Spr	Clay Sum
Sediment size:		>2000μ		2000-500μ		500-62μ		62-4μ		<4μ	
C	Channel Bottom	60.5[1]	4.4	30.4	57.7[2]	9.1	37.9				
C	Channel side		97.0		1.0		0.9		0.6		0.5
C	MLLW		62.5		20.8		12.3		3.4		1.0
C	+1.22 m		69.5		10.8		17.0		0.7		2.0
C	+2.14 m						17.7		65.2		17.0
CP	Channel Bottom		99.2	4.1	0.4	29.9	0.2	55.0	0.1	11.0	0.1
CP	Channel side	23.1		4.2		15.4	17.1	42.7	61.7	14.2	21.1
CP	MLLW		2.2		7.5		61.4		24.8		4.0
CP	+1.22 m		15.0		6.8		32.0		39.2		6.9
CP	+2.14 m		87.3		3.0		3.7		4.7		1.2
M	MLLW	25.3		31.1	4.5	30.1	24.9	10.7	60.1	2.7	10.5
M	+1.22 m				0.3	22.0	29.2	66.4	57.3	11.6	13.2
M	+2.14 m					1.4	4.1	90.8	79.2	7.8	16.7
MC	MLLW					4.6	5.7	83.8	80.1	11.6	14.2
MC	+1.22 m					5.7	11.0	79.5	69.6	14.6	15.2
MC	+2.14 m					4.9	1.7	84.1	81.4	11.0	16.9
MI	Channel Bottom	0.5		1.8	0.4	39.7	64.5	48.6	27.6	9.3	7.5
MI	Channel side	3.5		7.8	0.4	48.0	18.1	30.9	64.7	9.8	16.7
MI	MLLW				0.3		27.7		60.9		11.1
MI	+1.22 m				0.4		26.0		64.9		8.7
MI	+2.14 m				1.7		84.3		2.7		11.3
X	Channel Bottom	7.2	17.6	8.7	10.2	62.4	46.0	16.2	20.5	5.4	5.6
X	Channel side				0.2	65.2	96.9	24.3	1.8	10.4	1.0
WF	Channel bottom	1.8		1.9	2.4	93.8	97.5	0.5		1.9	
WF	Channel side			0.6	0.6	96.6	99.0	1.1	0.3	1.7	0.1

To upriver (East) ↔ (West) to open ocean

Table 1. (continued)

	Sediment size:	>2000μ		2000-500μ		500-62μ		62-4μ		<4μ	
		Gravel		Coarse Sand		Fine Sand		Silt		Clay	
Site	Elevation	Spr	Sum	Spr	Sum	Spr	Sum	Spr	Sum	Spr	Sum
DD	Bottom		3.7	0.8	31.3	<u>99.2</u>	<u>65.0</u>				
SJ	Bottom		87.5		3.8		8.5		0.2		0.2

[1] Percentage of sample occupied by each size class (by weight).

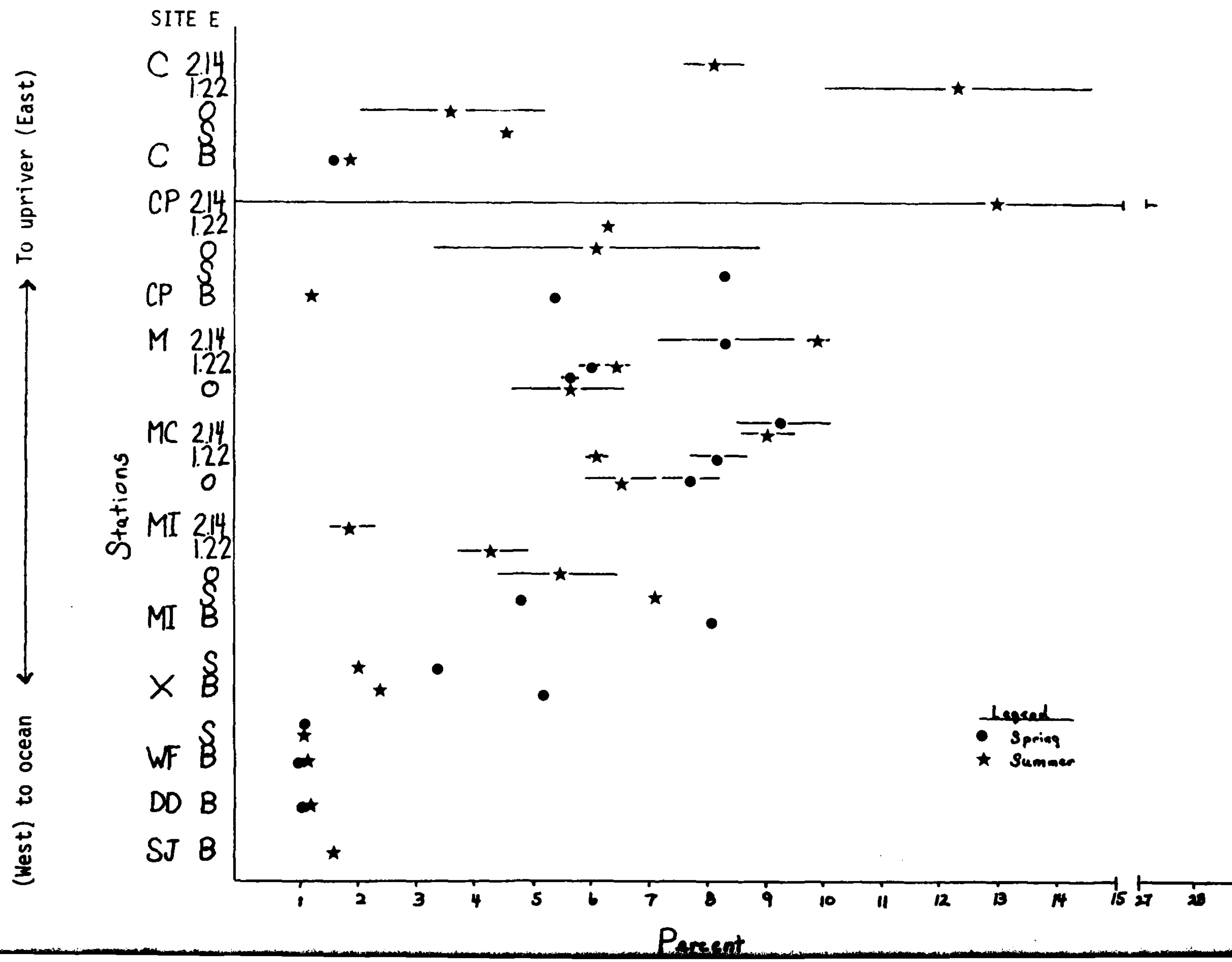
[2] Underlined values denote largest fraction by site and season.

Table 2. Total volatile solids of sediment samples from all benthic sampling sites, Grays Harbor, 1980.

		Percent[1] Total Volatile Solids			
	Season:	Spring		Summer	
Site	Elevation	Sample 1	Sample 2	Sample 1	Sample 2
C	Channel Bottom	1.68		2.01	
C	Channel Side			4.68	
C	MLLW			2.12	5.26
C	+1.22 m			10.09	14.75
C	+2.14 m			7.65	8.75
CP	Channel Bottom	5.53		1.29	
CP	Channel Side	8.84		8.82	
CP	MLLW			3.41	8.96
CP	+1.22 m			6.41	
CP	+2.14 m			27.05	
M	MLLW	5.67	5.80	4.71	6.65
M	+1.22 m	5.91	6.21	6.31	6.77
M	+2.14	7.17	9.60	9.89	10.12
MC	MLLW	7.29	8.25	5.99	7.20
MC	+1.22 m	7.81	8.82	6.18	6.27
MC	+2.14 m	8.59	10.22	8.75	9.55
MI	Channel bottom	8.16			
MI	Channel Side	4.85		7.20	
MI	MLLW			4.54	6.61
MI	+1.22 m			3.81	4.96
MI	+2.14			1.60	2.36
X	Channel Bottom	5.32		2.53	
X	Channel Side	3.52		2.14	
WF	Channel Bottom	1.12		1.22	
WF	Channel Side	1.21		1.21	
DD	Bottom	1.23		1.29	
SJ	Bottom			1.72	

1 Percentage of weight of sample occupied by total volatile solids.

FIGURE 1. Range and average values of total volatile solids by station, Grays Harbor, 1980.



Appendix C

Abundance of Benthic Invertebrates

Table 1. Density per m^2 at each intertidal station by general category, at Cosmopolis, 1980-1981.

Elevation[1]	Category	Season: Spring	Summer	Autumn	Winter	Total
MLLW	Crustacea	9,242	25,909	18,545	9,545	64,241
	Annelida	6,970	28,485	8,182	3,182	46,819
	Mollusca	-0-	151	-0-	-0-	151
	Other	152	455	303	-0-	910
	TOTAL	16,364	55,000	23,030	12,727	112,121
1.22	Crustacea	757	6,212	4,091	1,061	12,121
	Annelida	19,849	38,940	8,485	34,091	101,365
	Mollusca	-0-	-0-	-0-	-0-	-0-
	Other	606	151	-0-	303	1,060
	TOTAL	21,212	45,303	12,576	35,455	114,546
2.14	Crustacea	152	303	1,515	-0-	1,970
	Annelida	30,455	26,061	49,394	8,636	114,546
	Mollusca	-0-	-0-	-0-	-0-	-0-
	Other	151	-0-	758	1,212	2,121
	TOTAL	30,758	26,364	51,667	9,848	118,637

[1] Elevation in meters to mean lower low water.

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Table 2. Density per m^2 at each intertidal station, by general category, at Cow Point, 1980-1981.

Elevation[1]	Category	Season Spring	Summer	Autumn	Winter	Total
MLLW	Crustacea	29,697	85,152	10,606	18,333	143,788
	Annelida	9,242	3,030	10,303	5,909	28,484
	Mollusca	152	303	152	152	759
	Other	-0-	455	151	152	758
	TOTAL	39,091	88,940	21,121	24,546	173,789
1.22	Crustacea	10,455	12,273	3,333	5,152	31,213
	Annelida	1,515	2,727	1,364	3,030	8,636
	Mollusca	-0-	152	-0-	151	303
	Other	-0-	-0-	-0-	-0-	-0-
	TOTAL	11.970	15,152	4,697	8,333	40,152
2.14	Crustacea	1,970	23,636	45,303	45,000	115,909
	Annelida	42,879	216,819	152,728	121,364	533,790
	Mollusca	-0-	-0-	-0-	-0-	-0-
	Other	454	455	-0-	455	1,364
	TOTAL	45,303	240,910	198,031	166,819	651,063

[1] Elevation in meters relative to mean lower low water (MLLW).

Table 3. Density per m^2 at each station by general category, at the Marsh Establishment site, 1980-1981.

Elevation[1]	Category	Season				Total
		Spring	Summer	Autumn	Winter	
MLLW	Crustacea	1,818	11,970	455	1,970	16,213
	Annelida	3,031	4,697	1,515	6,667	15,910
	Mullusca	1,515	909	303	1,818	4,545
	Other	-0-		-0-	-0-	-0-
	TOTAL	6,364	17,576	2,273	10,455	36,668
1.22	Crustacea	4,242	6,364	4,091	1,364	16,061
	Annelida	96,970	48,485	15,606	62,728	223,789
	Mollusca	1,364	-0-	152	151	1,667
	Other	-0-	-0-	151	454	605
	TOTAL	102,576	54,849	20,000	64,697	242,122
2.14	Crustacea	5,455	4,924[2]	11,364	8,485	30,228
	Annelida	21,515	27,083	48,485	60,758	157,841
	Mollusca	151	-0-	-0-	151	302
	Other	-0-	-0-	151	-0-	151
	TOTAL	27,121	32,007	60,000	69,394	188,522

[1] Elevation in meters relative to mean lower low water (MLLW)

[2] Data derived from 4 core camples only.

Table 4. Density per m^2 at each station by general category, at the Marsh Control site, 1980-1981.

Elevation[1]	Category	Spring	Summer	Autumn	Winter	Total
		Season				
MLLW	Crustacea	1,212	1,364	7,121	758	10,455
	Annelida	1,970	2,273	3,485	1,212	8,940
	Mollusca	909	151	303	454	1,817
	Other	-0-	-0-	455	-0-	455
	TOTAL	4,091	3,788	11,364	2,424	21,667
1.22	Crustacea	1,364	1,364	7,424	4,697	14,849
	Annelida	4,848	8,636	12,425	7,273	33,182
	Mollusca	909	1,667	-0-	1,212	3,788
	Other	-0-	-0-	303	-0-	303
	TOTAL	7,121	11,667	20,152	13,182	52,122
.214	Crustacea	2,121	7,727	35,455	6,818	52,121
	Annelida	83,637	11,970	77,425	42,273	215,305
	Mollusca	152	303	151	455	1,061
	Other	-0-	152	303	-0-	455
	TOTAL	85,910	20,152	113,334	49,546	268,942

[1] Elevation in meters relative to mean lower low water (MLLW).

Table 5. Density per m^2 at each intertidal station by general category, at Moon Island, 1980-1981.

Elevation[1]	Category	Season: Spring	Summer	Autumn	Winter	Total
MLLW	Crustacea	5,303	4,091	303	568[2]	10,265
	Annelida	909	7,121	1,667	1,136	10,833
	Mollusca	606	1,667	1,060	568	3,901
	Other	152	-0-	-0-	190	342
	TOTAL	6,970	12,879	3,030	2,462	25,341
1.22	Crustacea	1,061	1,667	2,121	5,303	10,152
	Annelida	2,121	1,212	4,394	3,788	11,515
	Mollusca	758	454	909	606	2,727
	Other	151	-0-	152	152	455
	TOTAL	4,091	3,333	75,76	9,849	24,849
2.14	Crustacea	1,364	454	151	-0-	1,969
	Annelida	28,030	2,879	2,879	1,970	35,758
	Mollusca	606	1,061	2,576	2,727	6,970
	Other	-0-	-0-	-0-	152	152
	TOTAL	30,000	4,394	5,606	4,849	44,849

[1] Elevation in meters relative to mean lower low water (MLLW).

[2] Data derived from 4 core samples only.

Table 6. Density per m^2 at the bottom and side of the navigation channel, by general category, at Cosmopolis, 1980-1981.

Elevation	Category	Season: Spring	Summer	Autumn	Winter	Total
Bottom	Crustacea	300	850	350	12,000 [1]	13,500
	Annelida	38,755	1,050	39,495	3,800	83,100
	Mollusca	-0-	-0-	60	-0-	60
	Other	1,350	400	685	-0-	2,435
	TOTAL	40,405	2,300	40,590	15,800	99,095
Side	Crustacea	36,680	30,300	39,100*	39,300	145,380
	Annelida	3,500	4,700	4,900*	100	13,200
	Mollusca	-0-	-0-	-0-*	-0-	-0-
	Other		250	-0-*	200	450
	TOTAL	40,180	32,250	44,000*	39,600	159,030

[1] Data derived from one van Veen grab sample.

Table 7. Density per m^2 at the bottom and side of the navigation channel, by general category, at Cow Point, 1980-81.

Elevation	Category	Spring	Summer	Autumn	Winter	Total
		Season				
Bottom	Crustacea	185	2,755	1,155	105	6,200
	Annelida	1,530	7,650	6,900	5	16,085
	Mollusca	-0-	300	850	15	1,165
	Other	65	-0-	-0-	5	70
	TOTAL	1.780	12,705	8,905	130	23,520
Side	Crustacea	35	50	250	30	365
	Annelida	605	1,350	2,400	620	4,975
	Mollusca	130	50	50	30	260
	Other	-0-	-0-	50	10	60
	TOTAL	770	1,450	2,750	690	5,660

Table 8. Density per m^2 at the bottom and side of the navigation channel, by general category, at Moon Island, 1980-81.

Elevation	Category	Season Spring	Summer	Autumn	Winter	Total
Bottom	Crustacea	65	200	50	170	485
	Annelida	400	450	650	785	2,285
	Mollusca	65	50	300	165	580
	Other	-0-	-0-	-0-	-0-	-0-
	TOTAL	530	700	1,000	1,120	3,350
Side	Crustacea	25,605	650	5,650	460	32,365
	Annelida	1,215	400	5,650	1,680	8,945
	Mollusca	50	200	400	310	960
	Other	50	50		50	150
	TOTAL	26,920	1,300	11,700	2,500	42,420

Table 9. Density per m^2 at the bottom and side of the navigation channel, by general category, at the Top of the Cross-over Channel, 1980-1981.

Elevation	Category	Season: Spring	Summer	Autumn	Winter	Total
Bottom	Crustacea	70	350	1,410	235	2,065
	Annelida	425	200	1,350	720	2,695
	Mollusca	180	-0-	100	100	380
	Other	15	-0-	100	210	325
	TOTAL	690	550	2,960	1,265	5,465
Side	Crustacea	10	-0-	150	275	435
	Annelida	40	350	650	150	1,190
	Mollusca	285	150	150	50	635
	Other	5	-0-	-0-	15	20
	TOTAL	340	500	950	490	2,280

Table 10. Density per m^2 at the bottom and side of the navigation channel, by general category, at Whitcomb Flats, 1980-81.

Elevation	Category	Spring	Summer	Autumn	Winter	Total
		Season				
Bottom	Crustacea	280	110	660	40	1,030
	Annelida	1,030	1,750	850	255	3,885
	Mollusca	25	205	150	5	385
	Other	30	5	100	10	145
	TOTAL	1,365	2,070	1,700	310	5,445
Side	Crustacea	265	305	145	150	865
	Annelida	715	445	205	230	1,595
	Mollusca	60	55	30	60	205
	Other	10	-0-	25	20	55
	TOTAL	1,050	805	405	460	2,720

Table 11. Density per m^2 at the bottom, by general category, at the Deepwater Disposal site, 1980-1981.

Elevation	Category	Season Spring	Summer	Autumn	Winter	Total
Bottom	Crustacea	45	50	160	75	330
	Annelida	630	400	770	105	1,905
	Mollusca	35	-0-	35	20	90
	Other	20	350	45	140	555
	TOTAL	730	800	1,010	340	2,880

Table 12. Density per m^2 at the bottom by general category, at the South Jetty, 1980-1981.

Elevation	Category	Season: Spring	Summer	Autumn	Winter	Total
Bottom (Barnacles included)	Crustacea	32,130	13,875	9,995	1,270	57,270
	Annelida	5,050	675	485	160	6,370
	Mollusca	450	205	145	20	820
	Other	1,800	70	90	10	1,970
	TOTAL	39,430	14,825	10,715	1,460	66,430
Bottom (Barnacles not included)	Crustacea	5,000	1,120	695	40	6,855
	Annelida	5,050	675	485	160	6,370
	Mollusca	450	205	145	20	820
	Other	1,800	70	90	10	1,970
	TOTAL	12,300	2,070	1,415	230	16,015

Table 13. Density per m² and location of clams and large animals found in box[1] samples at Grays Harbor, Washington, 1980-1981.

Site	Elevation[2]		Macoma balthica				Mya arenaria				Total	Miscellaneous			
			Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Clams	Spring	Summer	Autumn	Winter
Cosmopolis	MLLW		0	0	0	0	0	0	0	0	0				
	1.22		0	0	0		0	0	0		0				
	TOTAL		0	0	0	0	0	0	0	0	0				
Cow Point	MLLW	Mean	128	16	85	37	5	0	5	0	276	21[4], 5[5],	43[6]	5[5]	
		S.D.[3]	32	0	61	9	9		9			24 9	40	9	
	1.22	Mean	0	0	0	5	0	0	0	0	5				
		S.D.				9									
	TOTAL		128	16	85	42	5	0	5	0	281				
Marsh Establishment Site	MLLW	Mean	437	251	107	171	75	27	16	133	1,217				
		S.D.	203	92	67	9	46	18	16	49					
	1.22	Mean	571	251	117	107	48	0	0	37	1,131				
		S.D.	51	96	9	49	16			33					
	2.14	Mean	107	48	101	75	0	0	0	0	331				
		S.D.													
	TOTAL		1,115	550	325	353	123	27	16	170	2,769				
Marsh Control	MLLW	Mean	427	59	69	224	0	0	11	0	790				
		S.D.	49	18	37	89			9						
	1.22	Mean	576	171	101	149	0	0	0	5	1,002	5[9]			
		S.D.	121	56	24	37				9		9			
	2.14	Mean	267	261	251	235	16	0	0	5	1,035		5[10]		
		S.D.	112	191	185	94	0			9			9		
	TOTAL		1,270	491	421	608	16	0	11	10	2,827				
Moon Island	MLLW	Mean	144	11	5	32	11	96	32	53	389		5[11]		5[12]
		S.D.	85	18	9	0	9	42	32	51			9		9
	1.22	Mean	421	75	75	37	27	32	32	32	736				5[13]
		S.D.	171	9	18	24	18	16	32	28					9
	2.14	Mean	1,675	219	368	491	213	59	37	21	3,083				
		S.D.	81	79	112	9	76	74	9	24					
	TOTAL		2,240	305	448	560	251	187	101	106	4,208				10

1 Box sample size: 1/16 m² x .3 m deep.
2 Elevation in meters relative to mean lower low water (MLLW)
3 Standard deviation
4 Cancer magister
5 Crab megalops
6 Pholis ornata
7 Pholis ornata
8 Flatfish juvenile
9 Abarenicola sp.
10 Crangon franciscorum
11 Upogebia pugettensis
12 Cryptomya californica
13 Macoma nasuta

Table 14. Number of species present and density per m^2 of all benthic invertebrates on all intertidal stations by season at Grays Harbor, Washington, 1980-81.

		SPRING			SUMMER			AUTUMN			WINTER		
		MLLW[1]	1.22	2.14	MLLW	1.22	2.14	MLLW	1.22	2.14	MLLW	1.22	2.14
GOSMOPOLIS													
Number of Species	Mean	4.4	3.2	2.4	6.6	5.6	2.6	4.0	3.6	3.8	4.0	4.0	3.4
	S.D.[2]	1.1	1.9	.9	1.7	.9	.6	.7	.6	.8	1.0	1.2	.6
	C[3]	.25	.59	.38	.26	.16	.23	.18	.17	.21	.25	.30	.18
Number of Individuals	Mean	16,364	21,212	30,758	55,000	45,303	26,364	28,030	12,576	51,667	12,727	35,455	9,848
	S.D.	17,860	23,728	37,432	24,458	22,850	11,569	25,438	10,229	23,075	1,245	33,451	3,900
	C	1.09	1.12	1.22	.44	.50	.44	.91	.81	.45	.10	.94	.40
COW POINT													
Number of Species	Mean	7.2	4.0	3.2	7.4	4.8	5.8	6.2	3.6	5.8	6.0	5.4	9.0
	S.D.	2.6	1.0	1.1	5.6	1.1	2.5	3.4	1.5	1.8	4.1	1.7	3.2
	C	.36	.25	.34	.76	.23	.43	.55	.42	.31	.68	.31	.36
Number of Individuals	Mean	39,091	11,870	45,303	88,940	15,152	240,910	21,212	4,697	198,031	24,546	8,333	166,819
	S.D.	35,782	9,514	53,498	128,388	9,642	355,873	18,565	2,646	92,210	32,117	4,417	193,941
	C	.92	.79	1.18	1.44	.64	1.48	.88	.56	.47	1.31	.53	1.16
MARSH ESTABLISHMENT SITE													
Number of Species	Mean	4.4	7.6	4.4	6.0	6.2	2.5*	2.4	6.6	5.4	5.8	6.0	6.0
	S.D.	2.1	1.8	2.1	2.0	1.3	1.3	1.8	1.1	2.6	3.4	1.4	3.5
	C	.48	.24	.48	.33	.21	.52	.75	.17	.48	.59	.23	.58
Number of Individuals	Mean	6,364	102,576	27,121	17,576	54,848	32,007*	2,273	20,000	60,000	10,455	64,697	69,394
	S.D.	4,030	28,581	23,050	24,951	29,412	1,562	1,856	14,657	37,561	6,325	7,038	114,682
	C	.63	.28	.85	1.42	.54	.05	.82	.73	.63	.61	.11	1.65
MARSH CONTROL SITE													
Number of Species	Mean	3.2	4.0	5.6	3.8	5.0	4.4	5.0	5.8	6.8	2.4	5.4	7.0
	S.D.	.8	1.2	2.3	1.3	2.4	3.7	1.0	3.0	2.3	1.3	1.7	1.2
	C	.25	.30	.41	.34	.48	.84	.20	.52	.34	.54	.31	.17
Number of Individuals	Mean	4,091	7,121	85,910	3.788	11,667	20,152	11,364	20,152	113,334	2,424	13,182	49,546
	S.D.	1,268	1,571	53,584	1,515	8,845	28,232	3,513	13,810	99,066	1,728	5,042	21,012
	C	.31	.22	.62	.40	.76	1.40	.31	.69	.87	.71	.38	.42

Table 14. (continued)

		SPRING			SUMMER			AUTUMN			WINTER		
		MLLW	1.22	2.14	MLLW	1.22	2.14	MLLW	1.22	2.14	MLLW	1.22	2.14
MOON ISLAND													
Number of Species	Mean	3.2	3.6	6.0	5.6	3.2	3.4	3.0	5.2	2.4	2.8 [4]	5.0	2.6
	S.D.	2.4	1.5	2.5	2.3	1.6	.9	.7	1.8	1.1	1.5	2.0	.9
	C	.75	.42	.42	.41	.50	.26	.23	.35	.46	.54	.40	.35
Number of Individuals	Mean	6,970	4,091	30,000	12,879	3,333	4,394	3,030	7,576	5,606	2,462 [4]	9,849	4,849
	S.D.	10,184	2,247	17,609	7,481	2,183	1,355	1.198	5,541	2,431	14,34	7,026	2,247
	C	1.46	.55	.59	.58	.66	.31	.40	.73	.43	.58	.71	.46

1 Elevation in meters relative to mean lower low water (MLLW)

2 S.D. = Standard Deviation

3 C = Coefficient of variation = $\frac{\text{S.D.}}{\text{Mean}}$

4 Data used from 4 core samples only.

Table 15. Number of species present and density per m^2 of all benthic invertebrates on all subtidal stations by season at Grays Harbor, Washington, 1980-1981.

		SPRING		SUMMER		AUTUMN		WINTER	
		Bottom[1]	Side	Bottom	Side	Bottom	Side	Bottom	Side
COSMOPOLIS									
Number of Species	Mean	8.0	6.5	5.5	9.0	7.5	8.0[4]	7.0[4]	5.0[4]
	S.D.[2]	1.4	2.1	3.5	1.4	2.1	---	---	---
	C[3]	.18	.32	.64	.16	.28	---	---	---
Number of Individuals	Mean	40,405	40,180	2,300	35,250	40,590	44,000*	15,800*	39,600*
	S.D.	4,405	17.169	2,546	6,152	51,209	---	---	---
	C	.11	.43	1.11	.17	1.26	---	---	---
COW POINT									
Number of Species	Mean	12.5	4.0	11.0	3.5	14.0	3.5	3.5	7.5
	S.D.	2.1	1.4	2.8	2.1	1.4	.7	.7	3.5
	C	.17	.35	.25	.60	1.0	.20	.20	.47
Number of Individuals	Mean	1.780	770	12,705	1,450	8,905	2,750	130	690
	S.D.	2,022	891	8,620	1,768	3,528	3,323	71	28
	C	1.14	1.16	.68	1.22	.40	1.21	.55	.04
MOON ISLAND									
Number of Species	Mean	7.5	13.0	5.0	6.5	6.5	13.0	8.0	13.0
	S.D.	3.5	7.0	1.4	5.0	.7	4.2	1.4	.3
	C	.47	.54	.28	.77	.11	.32	.18	.23
Number of Individuals	Mean	530	26,920	700	1,300	1,000	11,700	1,120	2,500
	S.D.	14	37,024	141	1,131	0	4,950	962	1,556
	C	.03	1.38	.20	.87	0	.42	.86	.62
TOP OF THE CROSSOVER CHANNEL									
Number of Species	Mean	5.5	6.5	4.0	4.5	14.0	8.5	16.0	18.0
	S.D.	2.1	3.5	1.4	.7	0	2.1	2.8	5.7
	C	.38	.54	.35	.16	0	.25	.18	.32
Number of Individuals	Mean	690	340	550	500	2,960	950	4,150	490
	S.D.	721	198	71	0	905	71	5,303	283
	C	1.04	.58	.13	0	.31	.07	1,28	.58
WHITCOMB FLATS									
Number of Species	Mean	13.0	18.5	8.0	9.5	6.5	13.5	10.0	11.5
	S.D.	2.8	3.5	2.8	2.1	3.5	.7	2.8	.7
	C	.22	.19	.35	.22	.54	.05	.28	.06
Number of Individuals	Mean	1,365	1,050	2,070	805	1,700	405	310	460
	S.D.	191	127	2,305	417	1,697	120	127	156
	C	.14	.12	1.11	.52	1.00	.30	.41	.34

Table 15. (continued)

		SPRING		SUMMER		AUTUMN		WINTER	
		Bottom	Side	Bottom	Side	Bottom	Side	Bottom	Side
DEEPWATER DISPOSAL SITE									
Number of Species	Mean	15.0		6.0		17.0		11.5	
	S.D.	0		1.4		2.8		.7	
	C	0		.23		.16		.06	
Number of Individuals	Mean	730		800		1,010		340	
	S.D.	778		424		198		28	
	C	1.07		.53		.20		.08	
SOUTH JETTY									
Number of Species	Mean	27.0		11.5		20.0		13.0*	
	S.D.	2.8		3.5		19.8		---	
	C	.10		.30		.99		---	
Number of Individuals	Mean	39,430		14,825		10,715		1,460 [4]	
	S.D.	4,907		20,754		14,163		---	
	C	.12		1.40		1.32		---	
Number of Individuals (without barnacles)	Mean	12,300		2,070		1,415		230 [4]	
	S.D.	2,546		2,729		1,153		---	
	C	.21		1.32		.81		---	

[1] Elevation: Bottom and side of navigation channel

[2] S.D. = Standard deviation

[3] C = Coefficient of variation = $\frac{S.D.}{Mean}$

[4] Only one van Veen grab sample collected.

Appendix D

Wet Weights

The following information pertains to Tables 1 through 16, Appendix D.

Values in parenthesis include larger organisms that usually would overshadow the aggregate contribution of other organisms to the overall sample biomass.

Blank = no organisms found

---- = sample taken and wet weight for that group less than 0.0001 g.

Table 1. Wet weights of major groups of organisms found in core samples at Cosmopolis, Grays Harbor, Washington, 1980-1981 (g/m^2).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
		SPRING				
MLLW						
C-0-1	.606	1.742			.046	2.394
C-0-2	.833	2.349				3.182
C-0-3	3.258	8.258				11.516
C-0-4	3.333	1.818			----	5.151
C-0-5	10.682	41.970				52.652
TOTAL	18.712	56.137			.046	74.895
MEAN	3.743	11.227			.009	14.979
S.D.[3]	4.088	17.402			.020	21.362
1.22						
C-4-1	2.879					2.879
C-4-2		.076				.076
C-4-3	11.667	1.136				12.803
C-4-4	2.273				.076	2.349
C-4-5	2.652	.758			.227	3.637
TOTAL	19.471	1.970			.303	21.744
MEAN	3.894	.394			.061	4.349
S.D.	4.494	.523			.099	4.909
2.14						
C-7-1	.606					.606
C-7-2	1.742					1.742
C-7-3	2.727					2.727
C-7-4	32.046					32.046
C-7-5	2.272	.152			----	2.425
TOTAL	39.394	.152				39.546
MEAN	7.879	.030				7.909
S.D.	13.522	.068				13.517
		SUMMER				
MLLW						
C-0-1	11.121	1.674	6.364			19.159
C-0-2	8.364	1.250			.129	9.743
C-0-3	11.652	4.955			.121	16.728
C-0-4	15.349	7.129			.129	22.607
C-0-5	9.606	29.250				38.856
TOTAL	56.092	44.258	6.364		.379	107.093
MEAN	11.218	8.852	1.273		.076	21.419
S.D.	2.646	11.657	2.846		.069	10.827

Table 1. (continued)

SUMMER (cont'd) Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
1.22						
CP-4-1		36.970				36.970
CP-4-2	.008	6.409				6.417
CP-4-3	.045	.045				.090
CP-4-4	.053	21.265				21.318
CP-4-5	.106	48.455	.053			48.614
TOTAL	.212	113.144	.053			113.409
MEAN	.042	22.629	.011			22.682
S.D.	.042	20.296	.024			20.331
2.14						
CP-7-1	3.758	92.531			1.652	97.941
CP-7-2	6.364	115.713				122.077
CP-7-3	.447	31.053				31.500
CP-7-4	.864	11.599				12.463
CP-7-5	.508	34.432			----	34.940
TOTAL	11.941	285.328			1.652	298.921
MEAN	2.388	57.066			.330	59.784
S.D.	2.612	44.591			.739	47.415
AUTUMN						
MLLW						
CP-0-1	4.303	.015	.621		.008	4.947
CP-0-2	.091	.015				.106
CP-0-3	.705	.076			2.523	3.304
CP-0-4	6.341	.939		(248.244)		7.280 (255.524)
CP-0-5	8.697	3.189		(94.319)		11.886 (106.205)
TOTAL	20.137	4.234	.621	(342.563)	2.531	27.523 (370.086)
MEAN	4.027	.847	.124	(68.513)	.506	5.505 (74.017)
S.D.	3.666	1.367	.278	(108.457)	1.127	4.421 (110.922)
1.22						
CP-4-1		1.833				1.833
CP-4-2	.015	9.886				9.901
CP-4-3	1.939	7.159				9.098
CP-4-4		19.349				19.349
CP-4-5	.098	7.136				7.234
TOTAL	2.052	45.363				47.415
MEAN	.410	9.073				9.483
S.D.	.855	6.444				6.349

Table 1. (continued)

AUTUMN (cont'd) Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
2.14						
CP-7-1	23.409	70.076				93.485
CP-7-2	9.849	12.121				21.970
CP-7-3	2.879	6.136				9.015
CP-7-4	1.849	442.177		1.242		445.268
CP-7-5	.523	177.236				177.759
TOTAL	39.509	707.746		1.242		747.497
MEAN	7.702	141.549		.248		149.499
S.D.	5.569	.437		.057		5.802
W I N T E R						
MLLW						
C-0-1	5.280	4.023				
C-0-2	1.886	7.856				
C-0-3	2.409	4.788			.068	
C-0-4	1.008	missing				
C-0-5	.856	2.591				
TOTAL	11.439				.068	
MEAN	2.288	4.815			.014	7.117
S.D.	1.790				.030	
1.22						
C-4-1	.197	.348				.545
C-4-2	.129	.871				1.000
C-4-3	47.993	2.902				50.895
C-4-4	5.485	.598			.121	6.204
C-4-5	11.379				.152	11.531
TOTAL	65.183	4.719			.273	70.175
MEAN	13.037	.944			.055	14.035
S.D.	20.082	1.141			.076	21.084
2.14						
C-7-1	.591				.114	.705
C-7-2	.811				.152	.963
C-7-3	.856				.015	.871
C-7-4	51.74				.174	5.348
C-7-5	.386				.068	.454
TOTAL	7.818				.523	8.341
MEAN	1.564				.105	1.668
S.D.	2.027				.064	2.066

[1] Size of core sample: 13.2 cm^2 x 8 cm deep.
[2] Elevation in meters relative to mean lower low water (MLLW)
[3] Standard deviation

Table 2. Wet weights of major groups of organisms found in core samples at Cow Point, Grays Harbor, Washington, 1980-1981 (g/m^2).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
			SPRING			
MLLW						
CP-0-1	1.136	.379		(4.546)	----	1.515 (6.061)[3]
CP-0-2	.152	2.121		(94.546)		2.273 (96.819)
CP-0-3	2.955	1.515	3.788			8.258 (8.258)
CP-0-4	.758	48.031		(628.791)		48.789 (677.580)
CP-0-5	5.606	7.121		(22.046)		12.727 (34.773)
TOTAL	10.607	59.167	3.788	(749.929)	----	73.562 (823.491)
MEAN	2.121	11.833	.758	(149.986)		14.712 (164.698)
S.D.[4]	2.211	20.399	1.694	(270.345)		19.594 (289.039)
1.22						
CP-4-1	missing	.152				
CP-4-2	.076	2.727				
CP-4-3	.303	9.546				
CP-4-4		8.333				
CP-4-5	.606	190.228				
TOTAL		210.986				
MEAN	.246	42.197				42.443
S.D.		82.843				
2.14						
CP-7-1	20.682	42.425				63.107
CP-7-2	.530				----	.530
CP-7-3	----	29.046				29.046
CP-7-4	2.803	103.561				106.364
CP-7-5	.076	.076			.152	.304
TOTAL	24.091	175.108			.152	199.351
MEAN	4.818	35.022			.030	39.870
S.D.	8.942	42.532			.068	45.254
			SUMMER			
MLLW						
CP-0-1						
CP-0-2	.015	.015				.030
CP-0-3	14.621	1.871	66.440	(575.238)	.008	82.940 (658.178)
CP-0-4	9.114	2.356		(292.388)	.030	11.500 (303.888)
CP-0-5	.780	8.621		(2,095.724)	5.811	15.212 (2,110.936)
TOTAL	24.530	12.863	66.440	(2,963.350)	5.849	109.682 (3,072.032)
MEAN	4.906	2.573	13.288	(592.670)	1.170	21.936 (614.606)
S.D.	6.654	3.546	29.713	(873.522)	2.595	34.773 (879.331)

Table 2. (continued)

SUMMER Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
1.22						
C-4-1	.417	.773			.227	1.417
C-4-2	.295	1.318				1.613
C-4-3	1.364	1.273				2.637
C-4-4	.470	3.364				3.834
C-4-5	1.439	3.114			.030	4.583
TOTAL	3.985	9.842			.257	14.084
MEAN	.797	1.968			.051	2.817
S.D.	.556	1.183			.099	1.378
2.14						
C-7-1	.462					
C-7-2	missing					
C-7-3	3.068					
C-7-4	3.591	.076				
C-7-5	1.447	.008				
TOTAL						
MEAN	2.142	.021				2.163
S.D.						
		AUTUMN				
MLLW						
C-0-1	5.992	5.053				11.045
C-0-2	.667	1.280			.030	1.977
C-0-3	1.167	7.091			.015	8.273
C-0-4	4.349	2.477				6.826
C-0-5	25.849	22.614				48.463
TOTAL	38.024	38.515			.045	76.584
MEAN	7.605	7.703			.009	15.317
S.D.	10.436	8.636			.013	18.819
1.22						
C-4-1	.023	2.091				2.114
C-4-2	.265	.091				.356
C-4-3	1.689	2.030				3.719
C-4-4	.030	.803				.833
C-4-5	.114	.061				.175
TOTAL	2.121	5.076				7.197
MEAN	.424	1.015				1.439
S.D.	.714	1.000				1.483

Table 2. (continued)

AUTUMN (cont'd)

Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total	
2.14							
C-7-1	.652	.030			.068	.750	
C-7-2	2.636	1.000				3.636	
C-7-3	14.652	.674			.136	15.462	
C-7-4	2.735				.038	2.773	
C-7-5	3.849	.220				4.069	
TOTAL	24.524	1.924			.242	26.690	
MEAN	4.905	.385			.048	5.338	
S.D.	9.492	181.554			.555	178.476	

W I N T E R

Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total	
MLLW							
CP-0-1	.348	.053				.401	
CP-0-2	.098	.227				.325	
CP-0-3	.864	5.629		(130.372)		6.493	(136.865)
CP-0-4	3.697	2.917	36.644	(100.826)	.129	43.387	(144.213)
CP-0-5	7.583	.061				7.644	
TOTAL	12.590	8.887	36.644	(231.198)	.129	58.250	(289.448)
MEAN	2.518	1.777	7.329	(46.240)	.026	11.650	(57.890)
S.D.	3.176	2.473	16.688	(64.172)	.058	18.060	(75.551)
1.22							
CP-4-1	.015	12.152					
CP-4-2	1.477	missing					
CP-4-3	.348	5.939	.189				
CP-4-4	.083	44.902					
CP-4-5	13.644	6.636					
TOTAL	15.567		.189				
MEAN	3.113	17.407	.038			20.558	
S.D.	5.916		.085				
2.14							
CP-7-1	.242	58.576				58.818	
CP-7-2	2.197	408.487				410.684	
CP-7-3	.561	32.152				32.713	
CP-7-4	.780	17.856				18.636	
CP-7-5	1.614	178.334			2.523	182.471	
TOTAL	5.394	695.405			2.523	703.322	
MEAN	1.079	139.081			.505	140.664	
S.D.	.805	163.348			1.128	164.242	

1 Size of core sample: 13.2 cm^2 x 8 cm deep.
2 Elevation in meters relative to mean lower low water (MLLW)
3 Includes barnacles
4 Standard Deviation

Table 3. Wet weights of major groups of organisms found in core samples at the Marsh Establishment site, Grays Harbor, Washington, 1980-1981 (g/m^2).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
			SPRING			
MLLW						
M-0-1	.076	1.061	34.697			35.834
M-0-2	9.243	.030	110.986			120.259
M-0-3	.076	.076				.152
M-0-4	1.136		.833	29.394		31.363
M-0-5	.076	.227		33.788		34.091
TOTAL	10.607	1.394	146.516	63.182		221.699
MEAN	2.121	.279	29.303	12.636		44.340
S.D.[3]	4.007	.446	48.034	17.373		44.895
1.22						
M-4-1	35.758	3.712	38.258			77.728
M-4-2	16.970	4.318	.758			22.046
M-4-3	8.030	2.107	78.485			88.712
M-4-4	28.182	2.689	.833			21.704
M-4-5	5.758	2.803	7.046			15.607
TOTAL	94.698	15.719	125.380			235.797
MEAN	18.940	3.144	25.076			47.159
S.D.	12.893	.855	33.654			33.638
2.14						
M-7-1	1.136	2.046				3.182
M-7-2	.076	.076	247.047			247.199
M-7-3	4.773	.530				5.303
M-7-4	.758	.682				1.440
M-7-5	28.940	12.273				41.213
TOTAL	35.683	15.607	247.047			298.337
MEAN	7.137	3.121	49.409			59.667
S.D.	12.324	5.168	110.483			106.119
			SUMMER			
MLLW						
M-0-1	3.189	8.197		46.144	.015	57.545
M-0-2	4.742	.038	23.614			28.394
M-0-3	5.409		74.796			80.205
M-0-4	.705	.008		3.455		4.168
M-0-5	1.697	.470	35.902			38.069
TOTAL	15.742	8.713	134.312	49.599	.015	208.381
MEAN	3.148	1.743	26.862	9.920	.003	41.676
S.D.	1.983	3.614	30.956	20.305	.007	28.864

Table 3. (continued)

SUMMER (cont'd) Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
1.22						
M-4-1	9.227	2.121				11.348
M-4-2	.530	3.462				3.992
M-4-3	6.038	1.205				7.243
M-4-4	.742	.462				1.204
M-4-5	8.780	5.667				14.447
TOTAL	25.317	12.917				38.234
MEAN	5.063	2.583				7.647
S.D.	4.223	2.055				5.361
2.14						
M-7-1	.053					
M-7-2	1.492	17.568				
M-7-3	.402					
M-7-4	.455	3.129				
M-7-5	missing					
TOTAL						
MEAN	.601	5.174				5.775
S.D.						

<u>A U T U M N</u>

Elevation	Annelids	Crustaceans	Clams	Barnacles	Other	Total
MLLW						
M-01-	.167	.348	1.992			2.507
M-0-2	1.136		1.030			2.166
M-0-3	.114	.477				.591
M-0-4	-------------nothing found-----------------------					-0-
M-0-5	.061					.061
TOTAL	1.478	.825	3.022			5.325
MEAN	.296	.165	.604			1.065
S.D.	.474	.230	.895			1.189
1.22						
M-4-1	3.174	.136	.439		.083	3.832
M-4-2	1.417	.644				2.061
M-4-3	3.545	2.091				5.636
M-4-4	4.962	.455		1.068		6.485
M-4-5	16.818	1.841				18.659
TOTAL	29.916	5.167	.439	1.068	.083	36.673
MEAN	5.983	1.033	.088	.214	.017	7.335
S.D.	6.187	.875	.196	.478	.037	6.556

Table 3. (continued)

AUTUMN (cont'd) Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
2.14						
M-7-1	1.909	1.962				23.871
M-7-2	.326					.326
M-7-3	.159	1.371			.106	1.636
M-7-4	2.288	1.455				3.743
M-7-5	7.697	.402				8.099
TOTAL	12.379	25.190			.106	37.675
MEAN	2.476	5.038			.021	7.535
S.D.	3.066	9.481			.047	9.596
W I N T E R						
MLLW						
M-0-1	7.508	1.038	.333			8.879
M-0-2	8.636	2.015	1.523			12.174
M-0-3	1.667					1.667
M-0-4	5.864	11.667	53.735			71.266
M-0-5	2.879	.174	.076			3.129
TOTAL	26.554	14.894	55.667			97.115
MEAN	5.311	2.979	11.122			19.423
S.D.	2.974	4.922	23.823			29,292
1.22						
M-4-1	2.780	.568			.280	3.628
M-4-2	6.197	.121				6.318
M-4-3	2.159	5.765	2.167			10.091
M-4-4	5.886	2.583			.053	8.522
M-4-5	6.500	2.523				9.023
TOTAL	23.522	11.560	2.167		.333	37.582
MEAN	4.704	2.312	.433		.067	7.516
S.D.	2.063	2.230	.969		.121	2.572
2.14						
M-7-1	10.682	15.924				
M-7-2	1.348	5.750				
M-7-3	missing					
M-7-4	15.439	32.712	155.001			
M-7-5	.015	38.659				
TOTAL						
MEAN	6.871	23.271	38.750			68.882
S.D.						

1 Size of core sample: 13.2 cm^2 x 8 cm deep.
2 Elevation in meters relative to mean lower low water (MLLW)
3 Standard Deviation

Table 4. Wet weights of major groups of organisms found in core samples at the Marsh Control site, Grays Harbor, Washington, 1980-1981 (g/m^2).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
			S P R I N G			
MLLW						
MC-0-1	.227	.227	5.985			6.439
MC-0-2		.758	.682			1.440
MC-0-3	.152	.152	68.940			69.244
MC-0-4	.227	.076				.303
MC-0-5	.379	.076	6.439			6.894
TOTAL	.985	1.289	82.046			84.320
MEAN	.197	.258	16.409			16.864
S.D.[3]	.138	.287	29.513			29.428
1.22						
MC-4-1	1.742		118.637			120.379
MC-4-2	8.258	.227	2.046			10.531
MC-4-3	1.061	.379	11.440			12.880
MC-4-4	.985		3.258			4.243
MC-4-5	4.091	.227				4.318
TOTAL	16.137	.833	135.381			152.351
MEAN	3.227	.167	27.076			30.740
S.D.	3.081	.164	51.368			50.404
2.14						
MC-7-1	9.849					9.849
MC-7-2	11.818	2.652			1.288	15.758
MC-7-3	11.591					11.591
MC-7-4	20.076	3.106	350.835			374.017
MC-7-5	9.546	4.394				13.490
TOTAL	62.880	10.152	350.835		1.288	425.155
MEAN	12.576	2.030	70.167		.258	85.031
S.D.	4.313	1.961	156.898		.576	161.564
			S U M M E R			
MLLW						
MC-0-1	.136	.030				
MC-0-2	.159	.038	.061			
MC-0-3	.023	.083				
MC-0-4	.098					
MC-0-5	.258	missing				
TOTAL	.674		.061			
MEAN	.135	.038	.012			.185
S.D.	.086		.027			

Table 4. (continued)

SUMMER (cont'd) Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
1.22						
MC-4-1	1.636	.106	51.720			53.462
MC-4-2	4.674	.174				4.848
MC-4-3	.053	.098				.151
MC-4-4	16.091	.061	17.250			33.402
MC-4-5	.303	.977	8.924			10.204
TOTAL	22.757	1.416	77.894			102.067
MEAN	4.551	.283	15.579			20.413
S.D.	6.707	.390	21.440			22.461
2.14						
MC-7-1	.008		59.591			59.599
MC-7-2	19.894	14.607				34.501
MC-7-3	4.886	4.205	29.697		11.000	49.788
MC-7-4	2.121					2.121
MC-7-5	.023	1.621				1.644
TOTAL	26.932	20.433	89.288		11.000	147.653
MEAN	5.386	4.087	17.858		2.200	29.531
S.D.	8.353	6.127	26.639		4.919	26.777
AUTUMN						
MLLW						
MC-0-1	3.091	.083	.189		.038	3.401
MC-0-2	.932	.409				1.341
MC-0-3	.015	.485			.015	.515
MC-0-4	.045	.477	.326		.038	.886
MC-0-5	.076	.424				.500
TOTAL	4.159	1.878	.515		.091	6.643
MEAN	.832	.376	.103		.018	1.329
S.D.	1.320	.167	.149		.019	1.208
1.22						
MC-4-1	.568	.197			.015	.780
MC-4-2	7.546	1.864				9.410
MC-4-3	15.523	2.727			.061	18.311
MC-4-4	8.470	.356				8.826
MC-4-5	.023	.508				.531
TOTAL	32.130	5.652			.076	37.858
MEAN	6.426	1.130			.015	7.572
S.D.	6.393	1.112			.026	7.348

Table 4. (continued)

AUTUMN (cont'd) Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
2.14						
MC-7-1	21.583	5.492			.023	27.098
MC-7-2	17.046	43.106				60.152
MC-7-3	12.197	6.621				18.818
MC-7-4	6.720	4.758	.515		.008	12.001
MC-7-5	5.591	315.570				321.161
TOTAL	63.137	375.547	.515		.031	439.230
MEAN	12.627	75.109	.103		.006	87.846
S.D.	6.788	135.399	.230		.010	131.729
			WINTER			
MLLW						
MC-0-1	.038	.280				.318
MC-0-2			.053			.053
MC-0-3	.038					.038
MC-0-4	.212	.061	3.326			3.599
MC-0-5	.023	1.038	.045			1.106
TOTAL	.311	1.379	3.424			5.114
MEAN	.062	.276	.685			1.023
S.D.	0.85	.441	1.477			1.504
1.22						
MC-4-1	.023	3.030	.212			3.265
MC-4-2	1.326	.083	86.152			87.561
MC-4-3	1.432	.765	1.371			3.568
MC-4-4	20.940	.083				21.023
MC-4-5	2.583	.629	.182			3.394
TOTAL	26.304	4.590	87.917			118.811
MEAN	5.261	.918	17.583			23.762
S.D.	8.812	1.221	38.335			36.471
2.14						
MC-7-1	14.364	.182				14.546
MC-7-2	13.720	3.902	.583			18.205
MC-7-3	3.189	2.432	10.235			15.856
MC-7-4	9.356	1.614				10.970
MC-7-5	2.652	2.258				4.910
TOTAL	43.281	10.388	10.818			64.487
MEAN	8.656	2.078	2.164			12.897
S.D.	5.582	1.350	4.519			5.176

1 Size of core sample: 13.2 cm^2 x 8 cm deep.
2 Elevation in meters relative to mean lower low water (MLLW)
3 Standard Deviation

Table 5. Wet weights of major groups of organisms found in core samples at Moon Island, Grays Harbor, Washington, 1980-1981 (g/m^2).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
			SPRING			
MLLW						
MI-0-1			7.273			7.273
MI-0-2		.076	5.379			5.455
MI-0-3	.303	.758	2.879			3.940
MI-0-4	.152	.076	1.136			1.364
MI-0-5	1.288	7.197			.227	8.712
TOTAL	1.743	8.107	16.667		.227	26.744
MEAN	.349	1.621	3.333		.045	5.349
S.D.[3]	.540	3.132	2.944		.102	2.867
1.22						
MI-4-1	1.439		4.621		.076	6.136
MI-4-2	2.273	.152	8.712			11.137
MI-4-3		.303	19.470			19.773
MI-4-4	.227		2.576			2.803
MI-4-5	.455	.076	1.364			1.895
TOTAL	4.394	.531	36.743		.076	41.744
MEAN	.879	.106	7.349		.015	8.349
S.D.	.953	.127	7.328		.034	7.341
2.14						
MI-7-1	7.500					7.500
MI-7-2	38.864	.076	5.076			44.016
MI-7-3	6.364	1.591	1.818			9.773
MI-7-4	11.970					11.970
MI-7-5	8.561	.076	7.652			16.289
TOTAL	73.259	1.743	14.546			89.548
MEAN	14.652	.349	2.909			17.910
S.D.	13.696	.696	3.366			14.950
			SUMMER			
MLLW						
MI-0-1	19.008	1.280	1.485			21.773
MI-0-2	38.652	.652	.470			39.774
MI-0-3	12.167	2.068	1.008			15.243
MI-0-4	6.311	.341	.348			7.000
MI-0-5	2.985	.061				4.046
TOTAL	80.123	4.402	3.311			87.836
MEAN	16.025	.880	.662			17.567
S.D.	13.920	.804	.585			14.237

Table 5. (continued)

SUMMER (cont'd) Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
1.22						
MI-4-1	7.682	1.409	.909			
MI-4-2	4.924	.515	3.720			
MI-4-3	1.947					
MI-4-4	.068	.242				
MI-4-5		missing	33.235			
TOTAL	14.621		37.864			
MEAN	2.924	.562	7.573			11.059
S.D.	3.328		14.426			
2.14						
MI-7-1	13.917	.258	19.864		.167	34.206
MI-7-2	7.500				.265	7.765
MI-7-3	21.727		.455			22.182
MI-7-4	11.061	.167				11.228
MI-7-5	2.962	.015	.311			3.288
TOTAL	57.167	.440	20.630		.432	78.669
MEAN	11.433	.088	4.126		.086	15.734
S.D.	7.062	.118	8.800		.123	12.465
			AUTUMN			
MLLW						
MI-0-1	.008	.136				.144
MI-0-2	.182		19.561			19.743
MI-0-3	11.909		.402			12.311
MI-0-4	1.174		.242			1.416
MI-0-5	1.962		.295			2.257
TOTAL	15.235	.136	20.500			35.871
MEAN	3.047	.027	4.100			7.174
S.D.	5.017	.061	8.644			8.531
1.22						
MI-4-1	.167	.038	3.371			3.576
MI-4-2	1.121	.174	2.447		.008	3.750
MI-4-3	6.985	.144				7.129
MI-4-4	.015		4.045			4.060
MI-4-5	4.167	.235				4.402
TOTAL	12.455	.591	9.863		.008	22.917
MEAN	2.491	.118	1.973		.002	4.583
S.D.	3.017	.097	1.888		.004	1.457

Table 5. (continued)

AUTUMN (cont'd) Elevation[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
2.14						
MI-7-1	4.780		13.780			18.560
MI-7-2	2.485	.833	4.386			7.704
MI-7-3	12.924		.462		.197	13.583
MI-7-4	.470		11.212			11.682
MI-7-5	3.121		2.068			5.189
TOTAL	23.780	.833	31.908		.197	56.718
MEAN	4.756	.167	6.382		.039	11.344
S.D.	4.820	.373	5.825		.088	5.204
			WINTER			
MLLW						
MI-0-1	.045		1.636			
MI-0-2	.023				.038	
MI-0-3	1.076	.129	.409			
MI-0-4	--------------------data not used--------------------					
MI-0-5	.023	.106				
TOTAL						
MEAN	.292	.059	.511		.010	.872
S.D.						
1.22						
MI-4-1	.091		3.227			3.318
MI-4-2	.235	3.061	24.871			28.167
MI-4-3	.076	2.129				2.205
MI-4-4	2.470	.250			.045	2.765
MI-4-5	.568	4.515	.992			6.075
TOTAL	3.440	9.955	29.090		.045	42.530
MEAN	.688	1.991	5.818		.009	8.506
S.D.	1.016	1.906	10.732		.020	11.091
2.14						
MI-7-1	.720		1.326			2.046
MI-7-2	6.500		.485			6.985
MI-7-3	.280		5.485			5.765
MI-7-4	6.500		4.083			10.583
MI-7-5	13.439		4.992		.697	19.128
TOTAL	27.439		16.371		.697	44.507
MEAN	5.488		3.274		.139	8.901
S.D.	5.365		2.240		.312	6.479

1 Size of core sample: 13.2 cm^2 x 8 cm deep.
2 Elevation in meters relative to mean lower low water (MLLW)
3 Standard deviation

Table 6. Wet weights of clams and other larger organisms found in spring box[1] samples at Grays Harbor, Washington, 1980, (g/m^2).

Site	Sample	MLLW[2] Clams	MLLW[2] Other	1.22 Clams	1.22 Other	2.14 Clams	2.14 Other	Combined Clam Mean
Cosmopolis		-------------------------no clams or other-------------						-0-
Cow Point	1	1.621	1.152,[3] 0[4]	0	0			
	2	23.430	.640, 4.405	0	0			
	3	12.152	2.386, 7.499	0	0			
	TOTAL	37.203	4.178,11.904	0	0			
	MEAN	12.401	1.393, 3.968	0	0			12.401
	S.D.	10.907	.898, 3.769					
Marsh Estab-	1	9.008		40.702		159.688		
lishment	2	16.928		24.835		186.891		
	3	35.405		21.141		30.027		
	TOTAL	61.341		86.678		3.76.606		
	MEAN	20.447		28.893		125.535		174.875
	S.D.	13.546		10.393		83.824		
Marsh Control	1	7.437		29.613	-0-	110.075		
	2	10.869		10.645	18.686	79.982		
	3	10.506		14.605	-0-	7.941		
	TOTAL	28.812		54.863	18.686	197.998		
	MEAN	9.604		18.288	6.229	65.999		93.891
	S.D.	1.885		10.006	10.788	52.483		
Moon Island	1	6.197		17.742		40.917 (701.679)		
	2	.467		9.834 (149.346)		35.446		
	3	5.947		19.875		40.224 (420.174)		
	TOTAL	12.611		47.451 (186.963)		116.587 (1,157.299)		
	MEAN	4.204		15.817 (62.231)		38.862 (385.766)		58.883 (452.291)
	S.D.	3.239		5.290 (75.373)		2.979 (334.447)		

1 Box sample size: $1/16m^2$ x .3m deep.
2 Elevation in meters relative to mean lower low water (MLLW)
3 Cancer magister
4 Pholis ornata
5 Standard deviation
6 Abarenicola sp.

Table 7. Wet weights of clams and other larger organisms found in summer box[1] samples at Grays Harbor, Washington, 1980, (g/m^2).

Site	Sample	MLLW[2] Clams	MLLW[2] Other	1.22 Clams	1.22 Other	2.14 Clams	2.14 Other	Combined Clam Mean
Cosmopolis		--------------------no clams or other------------------						
Cow Point	1	.790		-0-				
	2	.496		-0-				
	3	.384		-0-				
	TOTAL	1.670		-0-				
	MEAN	.557		-0-				.557
	S.D.[3]	.210						
Marsh Estab-	1	64.143		13.898		134.950		
lishment	2	35.234		33.696		15.858		
	3	14.253		7.834		-0-		
	TOTAL	113.630		55.428		150.808		
	MEAN	37.877		18.476		50.269		106.622
	S.D.	25.050		13.525		73.763		
Marsh	1	1.318		7.312		58.570	-0-	
Control	2	1.330		1.107		11.431	-0-	
	3	1.212		13.517		53.487	9.788[4]	
	TOTAL	3.860		21.936[5]		123.488	9.788	
	MEAN	1.287		7.312		41.163	3.263	49.762
	S.D.	.065				25.874	5.651	
Moon	1	1,076.701	4.390[6]	1.490		10.675		
Island	2	101.975	-0-	1.898		105.524		
	3	278.309	-0-	1.082		11.921		
	TOTAL	1,456.985	4.390	4.470[7]		128.120		
	MEAN	485.662	1.463	1.490		42.707		529.859
	S.D.	519.393	2.535			54.405		

1 Box sample size: 1/16m^2 x .3m deep
2 Elevation in meters relative to mean lower low water (MLLW)
3 Standard Deviation
4 Crangon franciscorum franciscorum
5 Data used from only 2 samples
6 Upogebia pugettensis
7 Data used from only 2 samples

Table 8. Wet weights of clams and other larger organisms found in autumn box[1] samples at Grays Harbor, Washington, 1980, (g/m^2).

Site	Sample	MLLW[2] Clams	MLLW[2] Other	1.22 Clams	1.22 Other	2.14 Clams	2.14 Other	Combined Clam Mean
Cosmopolis		-----------------no clams or other----------------------						
Cow Point	1	.163	-0-	-0-				
	2	12.000	-0-	-0-				
	3	9.392	9.872[3]	-0-				
	TOTAL	21.555	9.872	-0-				
	MEAN	7.185	3.291	-0-				7.185
	S.D.[4]	6.220	5.700					
Marsh Estab-lishment	1	2.240		6.832		113.568		
	2	2.601		20.784		97.840		
	3	5.379		21.408		9.344		
	TOTAL	10.220		49.024		220.752		
	MEAN	3.407		16.341		73.584		93.332
	S.D.	1.718		8.241		56.187		
Marsh Control	1	2.915		7.384		45.968		
	2	.157		13.302		29.808		
	3	19.936		3.094		111.696		
	TOTAL	23.008		23.780		187.472		
	MEAN	7.669		7.927		62.491		78.087
	S.D.	10.712		5.126		43.372		
Moon Island	1	-0-		13.424		101.936		
	2	152.688		1.574		406.960		
	3	569.442		304.896		37.264		
	TOTAL	722.130		319.894		545.160		
	MEAN	240.710		106.631		182.053		529.394
	S.D.	294.749		171.804		197.441		

1 Box sample size: $1/16m^2 \times .3m$
2 Elevation in meters relative to mean lower low water (MLLW)
3 *Pholis ornata*
4 Standard deviation

Table 9. Wet weights of clams and other larger organisms found in winter box[1] samples at Grays Harbor, Washington, 1981 (g/m[2]).

Site	Sample	MLLW[2] Clams	MLLW[2] Other	1.22 Clams	1.22 Other	2.14 Clams	2.14 Other	Combined Clam Mean
Cosmopolis		------------------------no clams or other--------------------						
Cow Point	1	1.517		-0-				
	2	.342		2.208				
	3	2.382	-0-					
	TOTAL	4.241		.736				
	MEAN	1.414		1.275				2.689
	S.D.[3]	1.024						
Marsh Estab-	1	176.197	-0-	7.957		.376		
	2	6.843	30.875[4]	9.832		29.512		
	3	4.117	-0-	3.408		-0-		
	TOTAL	187.157	30.875	21.197		29.888		
	MEAN	62.386	10.292	7.066		9.963		79.415
	S.D.	98.573	17.826	3.304		16.931		
Marsh Control	1	1.970		4.608		59.534		
	2	2.384		4.880		46.722		
	3	15.453		4.464		86.939		
	TOTAL	19.807		13.952		193.195		
	MEAN	6.603		4.651		64.398		75.651
	S.D.	7.668		.211		20.545		
Moon Island	1	681.344		1.230		148.850		
	2	2.032		.717		7.179		
	3	1,508.384		3.072	6.208			
	TOTAL	2,191.760		5.019		162.237		
	MEAN	730.587		1.673		54.079		786.339
	S.D.	754.382		1.239		82.076		

1 Box sample size: 1/16m^2 x .3m deep
2 Elevation in meters relative to mean lower low water (MLLW)
3 Standard deviation
4 Flatfish juvenile

Table 10. Wet weights of major groups of organisms found in van Veen grab samples at Cosmopolis, Grays Harbor, Washington, 1980-1981, (g/m^2).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
		SPRING				
Bottom						
SS-1B-1	1.033	.003			2.550	3.586
		(3.809)[3]				(7.392)
SS-1B-2	1.360	1.999			.030	3.389
TOTAL	2.393	2.002			2.580	6.975
		(5.808)				(10.781)
MEAN	1.197	1.001			1.290	3.488
		(2.904)				(5.391)
S.D.[4]	.231	1.411			1.782	.139
		(1.280)				(2.831)
Side						
SS-1S-1	2.880	24.784		35.683	.099	63.446
SS-1S-2	2.120	12.676		19.747	.105	34.648
TOTAL	5.000	37.460		55.430	.204	98.094
MEAN	2.500	18.730		27.715	.102	49.047
S.D.	.537	8.562		11.267	.004	20.363
		SUMMER				
Bottom						
SS-1B-1	.172	.307		.656	.018	1.153
SS-1B-2	.003	.018			---	.021
TOTAL	.175	.325		.656	.018	1.174
MEAN	.088	.163		.328	.009	.587
S.D.	.120	.204		.464	.013	.800
Side						
SS-1S-1	1.513	1.404		35.012	.003	37.932
SS-1S-2	2.394	14.556		16.726	.025	33.701
TOTAL	3.907	15.960		51.738	.028	71.633
MEAN	1.954	7.980		25.869	.014	35.817
S.D.	.623	9.300		12.930	.016	2.992
		AUTUMN				
Bottom						
SS-1B-1	.108	.030	.001		.047	.164
SS-1B-2	3.333	.076	.009		.696	4.114
TOTAL	3.419	.106	.010		.743	4.278
MEAN	1.709	.053	.005		.372	2.139
S.D.	2.296	.033	.006		.459	2.793

Table 10. (continued)

Elevation	Annelids	Crustaceans	Clams	Barnacles	Other	Total
Side						
SS-1S-1	10.142	27.224				37.366
SS-1S-2	-----------------------	no sample	collected	-----------------------		
TOTAL						
MEAN	10.142	27.224				37.366
S.D.						
W I N T E R						
Bottom						
SS-1B-1	38.696	9.643				48.339
SS-1B-2	-----------------------	no sample	collected	-----------------------		
TOTAL						
MEAN	38.696	9.643				48.339
S.D.						
Side						
SS-1S-1	.074	29.237		77.663	.002	106.976
SS-1S-2	-----------------------	no sample	collected	-----------------------		
TOTAL						
MEAN	.074	29.237		77.663	.002	106.976
S.D.						

1 van Veen grab sample size: 0.1m^2

2 Elevation, bottom and side of navigation channel.

3 Includes weight of *Saduria entomon*

4 Standard deviation

Table 11. Wet weights of major groups of organisms found in van Veen grab samples at Cow Point, Grays Harbor, Washington, 1980-1981 (g/m^2).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
		SPRING				
Bottom						
SS-2B-1	.062	2.194	.930			
SS-2B-2	.514	data missing	.272			
TOTAL	.576		1.202			
MEAN[3]	.288	2.194	.601			3.083
S.D.	.320		.465			
Side						
SS-2S-1	.001	.011 (2.187)[4]	.478			.490 (2.666)
SS-2S-2	.210		23.480			23.690
TOTAL	.211	.011 (2.187)	23.958			24.180 (26.356)
MEAN	.106	.006 (1.094)	11.979			12.090 (13.178)
S.D.	.148	.008 (1,546)	16.265			16.405 (14.866)
		SUMMER				
Bottom						
SS-2B-1	12.863	3.458	6.924	5.385		28.630
SS-2B-2	15.424	1.104 (2.275)[5]	3.687			20.215 (21.386)
TOTAL	28.287	4.562 (5.733)	10.611	5.385		48.845 (50.016)
MEAN	14.144	2.281 (2.867)	5.306	2.693		24.423 (25.008)
S.D.	1.811	1.665 (.837)	2.289	3.808		5.950 (5.122)
Side						
SS-2S-1		.017	.278			.295
SS-2S-2	.346					.346
TOTAL	.346					.346
MEAN	.173	.009	.139			.321
S.D.	.245	.012	.197			.036

Table 11. Wet weights of major groups of organisms found in van Veen grab samples at Cow Point, Grays Harbor, Washington, 1980-1981 (g/m[2]).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
SPRING						
Bottom						
SS-2B-1	.062	2.194	.930			
SS-2B-2	.514	data missing	.272			
TOTAL	.576		1.202			
MEAN[3]	.288	2.194	.601			3.083
S.D.	.320		.465			
Side						
SS-2S-1	.001	.011 (2.187)[4]	.478			.490 (2.666)
SS-2S-2	.210		23.480			23.690
TOTAL	.211	.011 (2.187)	23.958			24.180 (26.356)
MEAN	.106	.006 (1.094)	11.979			12.090 (13.178)
S.D.	.148	.008 (1,546)	16.265			16.405 (14.866)
SUMMER						
Bottom						
SS-2B-1	12.863	3.458	6.924	5.385		28.630
SS-2B-2	15.424	1.104 (2.275)[5]	3.687			20.215 (21.386)
TOTAL	28.287	4.562 (5.733)	10.611	5.385		48.845 (50.016)
MEAN	14.144	2.281 (2.867)	5.306	2.693		24.423 (25.008)
S.D.	1.811	1.665 (.837)	2.289	3.808		5.950 (5.122)
Side						
SS-2S-1		.017	.278			.295
SS-2S-2	.346					.346
TOTAL	.346					.346
MEAN	.173	.009	.139			.321
S.D.	.245	.012	.197			.036

Table 11. (continued)

Elevation	Annelids	Crustaceans	Clams	Barnacles	Other	Total
		AUTUMN				
Bottom						
SS-2B-1	10.095	.178	9.084			19.357
SS-2B-2	.096	.022	.387			.505
		(65.716)[6]				(66.199)
TOTAL	10.191	.200	9.471			19.862
		(65.894)				(85.556)
MEAN	5.096	.100	4.736			9.931
		(32.947)				(42.778)
S.D.	7.070	.110	6.150			13.330
		(46.342)				(33.122)
Side						
SS-2S-1	2.393	.019	2.474			4.886
SS-2S-2	.020	.001			.070	.091
TOTAL	2.413	.020	2.474		.070	4.977
MEAN	1.207	.010	1.237		.035	2.489
S.D.	1.678	.013	1.749		.050	3.391
		WINTER				
Bottom						
SS-2B-1	---	.012			---	.012
SS-2B-2	.001	.031	2.285			2.317
TOTAL	.001	.043	2.285			2.329
MEAN	.001	.022	1.143			1.165
S.D.	.001	.103	1.616			1.630
Side						
SS-2S-1	.515	---	.505			1.020
SS-2S-2	.080	---	.312	.311	.003	.706
TOTAL	.595	---	.817	.311	.003	1.726
MEAN	.298	---	.409	.156	.002	.863
S.D.	.308		.136	.220	.002	.222

[1] van Veen grab sample size: $0.1 m^2$

[2] Elevation, bottom and side of navigation channel

[3] Standard deviation

[4] Includes *Crangon franciscorum franciscorum*

[5] Includes *Cancer magister*

[6] Includes *Cancer magister*

Table 12. (continued)

Elevation	Annelids	Crustaceans	Clams	Barnacles	Other	Total
TOTAL	10.343	.045	10.473			20.861
MEAN	5.172	.023	5.237			10.431
S.D.	5.939	.032	4.818			10.788
Side						
SS-3S-1	10.775	2.219	.361		.001	13.356
SS-3S-2	11.537	.848	.238		.004	12.627
TOTAL	22.312	3.067	.599		.005	25.983
MEAN	11.156	1.534	.300		.003	12.992
S.D.	.539	.969	.087		.002	.515
			WINTER			
Bottom						
SS-3B-1	14.305	.008	1.697			16.010
SS-3B-2	.051	.005	1.379			1.435
TOTAL	14.356	.013	3.076			17.445
MEAN	7.178	.007	1.538			8.723
S.D.	10.080	.002	.225			10.306
Side						
SS-3S-1	.812	.046	2.563		---	3.421
SS-3S-2	2.477	.118	1.205		.122	3.922
TOTAL	3.289	.164	3.768		.122	7.343
MEAN	1.645	.082	1.884		.061	3.672
S.D.	1.177	.051	.961		.086	.354

[1] van Veen grab sample size: $0.1m^2$

[2] Elevation, bottom and side of navigation channel

[3] Standard deviation

[4] Includes *Cancer magister*

Table 12. Wet weights of major groups of organisms found in van Veen grab samples at Moon Island, Grays Harbor, Washington, 1980-1981 (g/m²).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
			SPRING			
Bottom						
SS-3B-1	.160	.070	4.321			4.551
SS-3B-2	1.500	.006	5.443			6.949
TOTAL	1.660	.076	9.764			11.500
MEAN	.830	.038	4.882			5.750
S.D.[3]	.948	.045	.793			1.696
Side						
SS-3S-1	.828	.043 (1.224)[4]	1.195			2.066 (3.247)
SS-3S-2	12.130	38.503	23.350		.340	74.323
TOTAL	12.958	38.503 (39.727)	23.350		.340	76.389 (77.570)
MEAN	6.479	19.273 (19.864)	12.273		.170	38.195 (38.785)
S.D.	7.992	27.195 (26.360)	15.666		.240	51.093 (50.258)
			SUMMER			
Bottom						
SS-3B-1	.181	.034	1.264			1.479
SS-3B-2	.782	.108			.004	.894
TOTAL	.963	.142	1.264			2.373
MEAN	.482	.071	.632		.002	1.187
S.D.	.425	.052	.894		.003	.414
Side						
SS-3S-1	.083	.265	.096		.002	.446
SS-3S-2	.019	.076	.121			.216
TOTAL	.102	.341	.217		.002	.662
MEAN	.051	.171	.109		.001	.331
S.D.	.045	.134	.018		.001	.163
			AUTUMN			
Bottom						
SS-3B-1	9.371	.045	8.643			18.059
SS-3B-2	.972		1.830			2.802

Table 13. Wet weights of major groups of organisms found in van Veen grab samples at the Top of the Crossover Channel, Grays Harbor, Washington, 1980-1981, (g/m²).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
		SPRING				
Bottom						
SS-4B-1	.088	.102	.397		.100	.597
SS-4B-2	1.930	(66.360)[3]	4.470			6.400 (72.760)
TOTAL	2.018	.012 (66.372)	4.867		.100	6.997 (73.357)
MEAN	1.009	.006 (33.186)	2.434		.050	3.499 (36.679)
S.D.[4]	1.303	.009 (46.915)	2.880		.071	4.103 (51.027)
Side						
SS-4S-1	.062	.152	1.848		missing	2.062
SS-4S-2	.052		1.106			1.158
TOTAL	.114	.152	2.954			3.220
MEAN	.057	.076	1.477			1.610
S.D.	.007	.107	.525			.639
		SUMMER				
Bottom						
SS-4B-1	1.839	.279				2.118
SS-4B-2	.342	.739				1.081
TOTAL	2.181	1.018				3.199
MEAN	1.091	.509				1.600
S.D.	1.059	.325				.733
Side						
SS-4S-1	2.046		.067			2.113
SS-4S-2	4.743		.572			5.315
TOTAL	6.789		.639			7.428
MEAN	3.395		.320			3.714
S.D.	1.907		.357			2.264
		AUTUMN				
Bottom						
SS-4B-1	.368	.393	.120	2.513	6.443	9.837
SS-4B-2	9.078	1.348 (29.148)[5]			.011	10.437 (37.237)

Table 13. (continued)

Elevation	Annelids	Crustaceans	Clams	Barnacles	Other	Total
TOTAL	9.446	1.741 (28.541)	.120	2.513	6.454	20.274 (47.074)
MEAN	4.723	.871 (14.271)	.060	1.257	3.227	10.137 (23.537)
S.D.	6.159	.675 (19.626)	.085	1.777	4.548	.424 (19.375)
Side						
SS-4S-1	19.753	.778				20.531
SS-4S-2	17.360	.028	.212			17.600
TOTAL	37.113	.806	.212			38.131
MEAN	18.557	.403	.106			19.066
S.D.	1.692	.530	.150			2.073
			WINTER			
Bottom						
SS-4B-1	1.209	.065	.874		.068	2.216
SS-4B-2	139.358	.186 (.305)[6]	.503 (723.213)[7]		11.230	151.277 (874.106)
TOTAL	140.567	.251 (.370)	1.377 (724.087)		11.298	153.493 (876.322)
MEAN	70.284	.125 (.185)	.689 (362.044)		5.649	76.747 (438.161)
S.D.	97.686	.086 (.170)	.263 (510.771)		7.893	105.402 (616.519)
Side						
SS-4S-1	.449	.413	.398		.062	1.322
SS-4S-2	.728	.216 (.309)[8]	.142		.165	1.251 (1.344)
TOTAL	1.177	.629 (.722)	.540		.227	2.573 (2.666)
MEAN	.589	.315 (.361)	.270		.114	1.287 (1.333)
S.D.	.197	.139 (.074)	.181		.073	.050 (.016)

[1] van Veen grab sample size: 0.1m^2

[2] Elevation, bottom and side of navigation channel.

[3] Includes Cancer magister

[4] Standard deviation

[5] Includes Cancer magister and Crangon franciscorum franciscorum

[6] Includes Callianassa californiensis

[7] Includes Clinocardium nuttallii

[8] Includes Archaeomysis grebnitzkii

Table 14. Wet weights of major groups of organisms found in van Veen grab samples at Whitcomb Flats, Grays Harbor, Washington, 1980-1981, (g/m²).

Elevation[2] Sample	Annelids	Crustaceans	Clams	Barnacles	Other	Total
		SPRING				
Bottom						
SS-5B-1	.450	.119	.100		.036	.705
		(.546)[3]				(1.132)
SS-5B-2	1.381	.053	.355		.068	2.307
		(.803)				(2.607)
TOTAL	1.831	.622	.455		.104	3.012
		(1.349)				(3.739)
MEAN	.916	.311	.228		.052	1.506
		(.675)			(1.870)	
S.D.[4]	.658	.272	.180		.023	1.133
		(.182)				(1.043)
Side						
SS-5S-1	.694	.308	.112	---	---	1.114
SS-5S-2	.263	.322	.496		.026	1.107
TOTAL	.957	.630	.608	---	.026	2.221
MEAN	.479	.315	.304		.013	1.111
S.D.	.305	.010	.272		.018	.005
		SUMMER				
Bottom						
SS-5B-1	.494	.971	.002		.047	1.514
SS-5B-2	.735		15.121		.109	15.965
TOTAL	1.229	.971	15.123		.156	17.479
MEAN	.615	.486	.7562		.078	8.740
S.D.	.170	.687	10.691		.044	10.218
Side						
SS-5S-1	1.186	.160	.013			1.359
SS-5S-2	3.595	3.504	.465			7.564
TOTAL	4.781	3.664	.478			8.923
MEAN	2.390	1.832	.239			4.462
S.D.	1.704	2.365	.320			4.388
		AUTUMN				
Bottom						
SS-5B-1	4.769	1.519	.069		---	6.357
		(7.535)				(12.373)
SS-5B-2	1.339	.202			7.251	8.792

Total 14. (continued)

Elevation	Annelids	Crustaceans	Clams	Barnacles	Other	Total
TOTAL	6.108	1.721 (7.737)	.069		7.251	15.149 (21.165)
MEAN	3.054	.861 (3.869)	.035		3.626	7.575 (10.583)
S.D.	2.425	.931 (5.185)	.049		5.127	1.722 (2.532)
Side						
SS-5S-1	.961	.043 (.095)			.083	1.087 (1.139)
SS-5S-2	.574	.217 (.421)	.080		.185	1.056 (1.260)
TOTAL	1.535	.260 (.516)	.080		.268	2.143 (2.399)
MEAN	.768	.130 (.258)	.040		.134	1.072 (1.200)
S.D.	.274	.123 (.231)	.057		.072	.022 (.086)
WINTER						
Bottom						
SS-5B-1	.732	.016 (.054)			.001	.749 (.787)
SS-5B-2	.135	.172 (.207)	.312		.009	.627 (.663)
TOTAL	.867	.188 (.261)	.312		.010	1.376 (1.450)
MEAN	.434	.094 (.131)	.156		.005	.688 (.725)
S.D.	.422	.110 (.108)	.221		.006	.086 (.088)
Side						
SS-5S-1	.304	.081 (.379)	.118		.106	.609 (.907)
SS-5S-2	.881	.068 (.596)	.354		.177	1.480 (2.008)
TOTAL	1.185	.149 (.975)	.472		.283	2.089 (2.915)
MEAN	.593	.075 (.488)	.236		.142	1.045 (1.458)
S.D.	.408	.009 (.153	.167		.050	.616 (.779)

Table 14. (continued)

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[1] van Veen grab sample size: $0.1m^2$

[2] Elevation, bottom and side of navigation channel

[3] Throughout the column; including *Archaeomysis grebnitzkii*

[4] Standard deviation

Table 15. Wet weights of major groups of organisms found in van Veen grab[1] samples at the Deepwater Disposal Area, Grays Harbor, Washington, 1980-1981, (g/m^2).

Bottom[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
			SPRING			
SS-6-1	.040	.035	.182			.257
SS-6-2	6.080	.062	.346		.462	6.950
TOTAL	6.120	.097	.528		.462	7.207
MEAN	3.060	.049	.264		.231	3.604
S.D.[3]	4.271	.019	.116		.327	4.733
			SUMMER			
SS-6-1	.185	.131			missing	
SS-6-2	.563		.251		.003	
TOTAL	.748	.131	.251			
MEAN	.374	.066	.126		.003	.569
S.D.	.267	.093	.177			
			AUTUMN			
SS-6-1	1.762	.523 (2.191)[4]	.032		.014	2.331 (3.999)
SS-6-2	5.272	.219 (.848)	.200		.200[5]	5.891 (6.520)
TOTAL	7.034	.742 (3.039)	.232		.214	8.222 (10.519)
MEAN	3.517	.371 (1.520)	.116		.107	4.111 (5.260)
S.D.	2.482	.215 (.950)	.119		.132	2.517 (1.783)
			WINTER			
SS-6-1	1.418	.002	.716		.016	2.152
SS-6-2	1.513	.779 (.926)	.335		.414	3.041 (3.188)
TOTAL	2,931	.781 (.928)	1.051		.430	5.193 (5.340)
MEAN	1.466	.391 (.464)	.526		.215	2.597 (2.670)
S.D.	.067	.549 (.653)	.269		.281	.629 (.733)

1 van Veen grab sample size: 0.1m^2
2 Elevation, only bottom existed
3 Standard deviation
4 Includes *Archaeomysis grebnitzkii*
5 Excludes sandlance weight

Table 16. Wet weights of major groups of organisms found in van Veen grab[1] samples at the South Jetty, Grays Harbor, Washington, 1980-1981, (g/m^2).

Bottom[2]	Annelids	Crustaceans	Clams	Barnacles	Other	Total
			SPRING			
SS-7-1	4.29	23.18	.60	(157.657)	7.77	35.840 (193.497)[3]
SS-7-2	2.60	30.57	1.50	(286.126)	1.49	36.160 (322.286)
TOTAL	6.89	53.75	2.10	(443.783)	9.26	72.000 (515.783)
MEAN	3.45	26.88	1.05	(221.892)	4.63	36.000 (257.892)
S.D.[4]	1.20	5.23	.64	(90.841)	4.44	.226 (91.068)
			SUMMER			
SS-7-1	.023	.031	1.290	(.021)	.002	1.346 (1.367)
SS-7-2	6.274	1.925	1.138	(519.494)	8.898	18.235 (537.729)
TOTAL	6.297	1.956	2.428	(519.515)	8.900	19.581 (539.096)
MEAN	3.149	.978	1.214	(259.758)	4.450	9.791 (269.548)
S.D.	4.420	1.339	.107	(367.323)	6.290	11.942 (379.265)
			AUTUMN			
SS-7-1	2.612	.203	1.336	(6.918)		4.151 (11.069)
SS-7-2	1.006	1.926 (57.93)[5]	.093	(351.500)	1.066	4,091 (411.595)[6]
TOTAL	3.618	2.129 (58.133)	1.429	(358.418)	1.066	8.242 (422.664)
MEAN	1.809	1.065 (29.067)	.715	(179.209)	.533	4.121 (211.332)
S.D.	1.136	1.218 (40.819)	.879	(243.656)	.754	.042 (283.215)
			WINTER			
SS-7-1	.593	.026	.006	(39.871)	.003	
SS-7-2	---------------------no sample collected------------------------					
TOTAL MEAN S.D.	.593	.026	.006	(39.871)	.003	.628 (40.499)

[1] van Veen sample size: $0.1m^2$

[2] Elevation, only bottom existed

[3] Includes barnacles

[4] Standard Deviation

[5] Includes Cancer magister and Cancer productus

[6] Includes crab and barnacles

Appendix E

Shannon-Weiner Diversity Values

Table 1. Shannon-Wiener Diversity (H*) values and Evenness (E) values for benthic invertebrate communities by site and station at Grays Harbor, 1980-1981.

Site and Station	SPRING		SUMMER		AUTUMN		WINTER	
	H*	E	H*	E	H*	E	H*	E
C-2.14	.748	.540	.700	.435	.761	.473	1.049	.757
C-1.22	.899	.409	1.105	.461	1.101	.614	.675	.307
C-MLLW	1.214	.553	1.096	.415	.878	.400	.978	.470
CP-2.14	.783	.377	.564	.220	1.143	.520	1.166	.389
CP-1.22	1.528	.696	1.510	.687	2.033	.883	2.053	.826
CP-MLLW	1.839	.679	1.996	.691	2.091	.754	1.669	.616
M-2.14	1.257	.524	.600	.373	1.005	.404	.927	.362
M-1.22	.593	.219	.928	.422	1.701	.663	.826	.359
M-MLLW	2.194	.883	2.337	.843	1.841	.946	1.926	.775
MC-2.14	.762	.331	1.648	.687	1.213	.460	1.407	.587
MC-1.22	1.545	.743	1.551	.647	1.637	.599	1.746	.728
MC-MLLW	1.632	.911	2.211	.922	1.489	.646	1.511	.939
MI-2.14	1.087	.401	1.875	.853	1.006	.625	1.104	.686
MI-1.22	1.959	.892	o.988	.905	2.024	.844	1.744	.702
MI-MLLW	1.444	.627	1.708	.712	1.822	.876	1.778	.914

Table 2. Shannon-Wiener Diversity (H*) values and Evenness (E) values for benthic invertebrate communities by site and station at Grays Harbor, 1980-1981.

Site and Station	SPRING		SUMMER		AUTUMN		WINTER	
	H*	E	H*	E	H*	E	H*	E
C-Side	.371	.179	.636	.276	.496	.255	.100	.072
C-Bottom	.212	.096	1.645	.791	.187	.078	.828	.425
CP-Side	.857	.532	1.049	.539	1.084	.605	1.106	.461
CP-Bottom	1.115	.402	1.738	.659	1.810	.626	1.356	.757
MI-Side	.640	.210	2.111	.917	2.045	.707	1.666	.576
MI-Bottom	1.645	.686	1.871	.852	2.016	.876	1.669	.696
X-Side	.810	.338	1.557	.967	2.507	.950	2.734	.860
X-Bottom	1.356	.652	1.768	.908	2.443	.830	1.505	.502
WF-Side	1.947	.605	2.186	.852	2.428	.840	2.285	.807
WF-Bottom	1.733	.625	1.352	.512	1.844	.801	2.205	.836
DD-Bottom	1.610	.494	2.014	.875	2.042	.642	2.491	.862
SJ-Bottom	3.002	.874	2.146	.774	2.555	.775	2.264	.944

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